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Articles suitable to the objectives mentioned above are invited for publication. An article sent for publication should normally not exceed ten typed pages and it should be exclusive to this journal. A copy of the article in floppy/CD may also be provided. Illustrations should be drawn with pen and indelible ink. Photographs (black and white) at least of postcard size, should be on glossy paper and should be properly packed to avoid damage in transit.

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Environmental Education and School Curriculum: Issues and Concerns

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ENVIRONMENTAL Education has been an integral component of school education in one form or the other for more than four decades. At present the concepts, issues and problems related to the environment are either integrated with different disciplines or introduced as a subject. For example, at the primary stage, environmental education (EE) is introduced as Environmental Studies as a subject. At the upper primary and the secondary stages, it is incorporated into different subjects; mainly science and social science. In the present paper we look at the roots of EE, its goals and objectives as they have evolved over the years and different approaches being followed in the country and elsewhere at school level.

Genesis of Environmental Education

The genesis of EE as we know today can be linked to three main educational movements: Nature Study; Outdoor Education and Conservation Education (Disinger and Monroe 1994).

The importance of environmental education was perhaps first realised by Wilber Jackman towards the end of nineteenth century. His publication titled "Nature Study for the Common Schools" in 1891 started a ***Nature Study Movement.*** His approach called for activities by the students outdoors rather than in the confines of classrooms. These activities, according to Louis Agassiz, emphasised students to "study nature, not books".

Outdoor Education as theorists like L. B. Sharp and Julian Smith called it in 1920's, had a very similar purpose. Nature study and outdoor education opened to students the dimensions of education that the classroom tended to isolate.

The Dust Bowl of 1930's awakened Americans to have a fresh look at the agricultural practices then followed and this gave rise to a new movement called ***Conservation Education***. The main objectives of the movement were to create awareness among Americans about the environmental problems and the importance of conserving various natural resources. Since then several other educational movements can be identified as forerunners and/or concurrent companions of environmental education (EE), such as Resource — Use Education, Progressive Education, Resource Management Education, Population Education, Energy Education, Citizenship Education and Global Education.

The Environmental Education as we know today has its roots in the deliberations of the Stockholm Conference on the Human Environment. Its Recommendation No. 96, in particular,

called for the development of environmental education as one of the most critical elements of an all-out attack on the World's environmental crisis. This new environmental education must be broad based and strongly related to the basic principles outlined in the United Nations Declaration on the New International Economic Order.

The EE essentially deals with humanity, nature and the interactive processes between them, which are complex and multi-dimensional. This has made the defining of EE a difficult task. For example, reflecting on EE Rene Dubos stated:

> We have collectively begun to engage in a kind of discovery of ourselves – who we are, where we belong, and where we are going.

Environmental scientists, educationists and practitioners have perceived EE in their own ways. To appreciate their views, let us have a look at EE as defined by some of them. This would reflect what various peoples or organisations think EE is all about.

1. According to the report of a Conference of African Educators, Nairobi 1968 —

   EE is to create awareness and an understanding of the evolving social and physical environment as a whole, its natural, man-made, cultural, spiritual resources, together with the personal use and conservation of these resources for development.

2. According to Dr William Stapp, University of Michigan, 1969 —

   EE is aimed at producing a citizenry that is knowledgeable concerning the biophysical environment and its associated problems, aware of how to solve these problems, and motivated to work toward their solution.

3. According to the National Anti-pollution Law, Japan 1969

   EE is to enable people to enjoy good health and high quality of life. It is vital by preventing harmful effects to human life or damage to the environment caused by pollution of air, water and soil; noise, vibration, noxious smells, etc.; caused by firms and individuals. The environment here includes animals and plants and their ecological systems, which are closely bound to the livelihood of people.

4. According to the IUCN Commission of Education, 1970 —

   EE is the process of recognising values and clarifying concepts in order to develop skills and attitudes necessary to understand and appreciate the inter-relatedness among man, his culture and his biophysical surroundings. EE also entails practice in decision-making and self-formulation of a code of behaviour about issues concerning environmental quality.

5. According to the Finnish National Commission for UNESCO 1974 —

   EE is a way of implementing the goals of environmental protection. EE is not a separate branch of science or subject or study. It should be

carried out according to the principle of life long integral education.

A close examination of the above definitions reveals that there is a considerable agreement regarding the general nature of EE. All the above statements are best summarised in the "Principles of Environmental Education" set forth by the Seminar on Environmental Education, Jammi, 1974.

1. EE is included in all thinking and activity, in culture in the broadest sense of the term, and its principle is the strategy of the survival of humanity and other forms of nature.
2. The strategy of survival is a global approach, which requires knowledge of natural science, technology, history and society; intellectual means for analysing and synthesising this knowledge for creating new modes of operation.
3. In addition to the strategy of survival, the quality of life must also be considered; the goals set for it, and the means humanity has at its disposal for maintaining the target quality.
4. EE aims at taking into consideration the principles of ecology in social planning, in various activities and in the economy, at both the national and international levels.

In fact, EE is for everyone. According to AA Schmieder, "It is an action process, it relates to, and builds upon, the work of almost all other subject areas; it is concerned with the dynamic interaction between humanity and nature; and it is directed at the improvement of the quality of existence for all living things; but, what is probably most important, EE is still in the process of becoming".

According to Volk and McBath 1997,

> The goal of EE is to develop a world population that is aware of, and concerned about, the environment and its associated problems, and which has the knowledge, skills and attitudes, motivation and commitment to work individually and collectively toward solutions of current problems and the prevention of new ones.

This was based on the deliberations in the 1975 International Workshop on EE sponsored by UNESCO and held at Belgrade, Yugoslavia. The ideas about EE were further elaborated during the Intergovernmental Conference on EE held in Tbilisi, USSR in 1978. The Conference outlined five categories of EE objectives (UNESCO/UNEP 1978).

- **Awareness**: To help social groups and individuals acquire an awareness of and sensitivity to the total environment and its allied problems.
- **Knowledge**: To help social groups and individuals gain a variety of experience in, and acquire a basic understanding of the environment and its associated problems.
- **Attitudes**: To help social groups and individuals acquire a set of values and feelings of concern for the environment and the motivation for actively participating in environmental improvement and protection.

- **Skills**: To help social groups and individuals acquire the skills for identifying and solving environmental problems.
- **Participation**: To provide social groups and individuals with an opportunity to be actively involved at all levels in working towards resolution of environmental problems.

Winther, Volk and Hungerford (1997) defined EE with one overarching goal and four sub-goals. The overarching goal of EE is —

To aid citizens in becoming environmentally knowledgeable and, above all, skilled and dedicated citizens who are willing to work, individually and collectively, toward achieving and/or maintaining a dynamic equilibrium between the quality of life and the quality of the environment.

The four sub-goals of EE as enumerated by them are —

- **Ecological foundations**: To provide learners with a strong foundation of knowledge of ecological concepts to permit them to make sound decisions with respect to environmental issues.
- **Conceptual Awareness**: To guide learners in becoming aware of how both individual and collective actions may result in environmental issues which may be resolved through investigation, evaluation, values clarification, decision-making and citizenship action.
- **Investigation and Evaluation**: To develop the knowledge and skills necessary to investigate environmental issues and evaluate alternative solutions for solving these issues.
- **Environmental Action Skills**: To develop the necessary skills for learners to take positive environmental action to achieve/maintain a dynamic equilibrium between the quality of life and the quality of the environment.

The above-mentioned definitions, objectives and goal have been the guiding factors in the design and development of curriculum of EE in India and in other countries. Efforts made in this direction in India and other countries are presented below.

Environmental Education in School Curriculum

Indian Scenario

The importance for providing environmental orientation to education, especially to school education, has been recognised in India as early as 1970s. The document titled "The Curriculum for the Ten-Year School – A Framework" developed by the National Council of Educational Research and Training (NCERT), New Delhi in 1975 identified environment education as one of the essential component of school education. Enumerating on the subjectwise instructional objectives and content, it stated:

"In the primary classes, the sciences should be taught as environmental

studies; in classes I and II as a composite course including both natural and the social environment, and later on as two subjects, viz., environmental studies I (natural sciences) and environmental studies II (social science). One need not lay down how much of this should be covered in a particular class. The purpose should not be to stuff the minds of the children with facts and information, but to sharpen their senses, to enable them to observe their environment and to enrich their experiences."

It further suggested, "flexibility in selection of teaching/learning situation to accommodate for the variations in the environment and experiences of children outside their school as well as variations due to geographical location".

The National Policy on Education (NPE - 1986) adopted by the Indian Parliament in 1986 again reiterated the importance and need for inclusion of EE as an integral component of education. The Policy states that the protection of the environment is a value which, along with certain values, must form an integral part of the curriculum at all stages of education. Further Para 8.15 of the Policy states:

"There is a paramount need to create a consciousness of the environment. It must permeate all ages and all sections of the society, beginning with the child. Environmental consciousness should inform teaching in schools and colleges. This aspect will be integrated in the entire educational process."

It implies that the EE must be oriented to meet the challenge of development without destruction. This has to be done keeping in mind the fact that much depletion and degradation of the environment has already been caused by the severe strain put on natural resources by the high population growth rate and the resulting struggle for survival and economic growth and development. The results of the strain are perceptible in the form of soil degradation, deforestation, loss of biodiversity, drainage of wetlands, threats to fish populations due to over-exploitation, decline in grasslands due to overstocking of cattle, critical fuel wood shortages, air and water pollution (especially in urban areas) and increased prevalence of environmentally related diseases.

It may be pointed that the NPE - 1986 perceives EE to permeate all ages and all sections of the society, which cannot be accomplished by the formal school system alone. The responsibility of imparting EE, therefore, has to be shared by all other sectors engaged in any kind of social or economic activities, be it related to production of goods and services or development of infrastructure. In fact, all agencies, whether governmental or non-governmental, can effectively participate in developing a proper understanding about the environment and its problems amongst different sections of the society. Thus, the objective of universalising EE can be achieved if the efforts of formal school system are supplemented with the efforts of other agencies including Non-

governmental Organisations (NGOs) through both formal and nonformal modes. It is in this context that the role of other departments of the government and NGOs assumes a significant role in serving the cause of EE.

Many a governmental agencies in our country have formulated a number of schemes and programmes for the promotion of EE. Notable among them are the Union Ministry of Human Resource Development (MHRD), Union Ministry of Environment and Forestry (MOEF), the Department of Science and Technology (DST), Govt. of India and their counterparts in the States. For example, the MHRD launched the "Scheme of Environmental Orientation to School Education" in 1988.

Similarly, the MOEF has established a number of institutes that offer diploma, undergraduate and postgraduate courses besides conducting in-service training courses on environment and forestry. Some major educational activities for schools initiated by the Ministry of Environment and Forestry are —

- Establishment of the National Museum of Natural History (NMNH) and their regional centres, which organise programmes regularly for the benefit of school children, college students, teachers, and general public.
- Active interaction with the UGC, CSIR, NCERT, and MHRD for introducing and expanding environmental concepts, themes, issues etc. in the curricula of schools and colleges.
- Pilot Project on Environment Education in School System, which has been launched in 1999, with the support of the World Bank. The main purpose of the project is to strengthen EE in the formal School System. It envisages introduction of EE through the process of infusion in existing subjects and not as a separate subject. The pilot project launched in eight States namely, Andhra Pradesh, Assam, Goa, Jammu and Kashmir, Maharashtra, Orissa, Punjab and Uttaranchal (100 schools in each State) is nearing completion. The project involves development of textbooks (infusion model) and orientation of all major stakeholders. Ten more States, namely Chhattisgarh, Haryana, Himachal Pradesh, Karanataka, Kerala, Madhya Pradesh, Sikkim, Tripura, Tamil Nadu and West Bengal have expressed their interest in this project.
- Organisation of the National Environment Awareness Campaign (NEAC), since 1986, for creating environmental awareness at all levels of the society.
- National Green Corps (Eco-clubs) is another programme with the aim of establishing Eco-clubs in at least 100 schools in each District of the country so as to cover around 55,000 schools.
- The MOEF has established nine Centres of Excellence with a view to strengthening awareness, research and training in priority areas of

environmental science and management.

A number of laboratories and research institutes of Department of Science and Technology (DST) are engaged in identifying and working out plausible solutions to environmental problems concerning industrial and production units. Some of the programmes that are specifically relevant in the context of school education are —

- The National Council of Science and Technology Communication (NCSTC), DST provides grants for many project proposals on issues and problems pertaining to environment and EE to both governmental and nongovernmental organisations. It also conducts a National Children Science Congress every year, which is preceded by district and state level Congress. A majority of projects undertaken by children are on issues and problems related to local environment.
- Vigyan Prasar, a voluntary organisation of the NCSTC, has established a network of voluntary organisations in the country and acts as clearing house to disseminate information on environment and the EE.

Effort of NCERT towards EE

The NCERT, an autonomous institution of the MHRD has been one of the pioneer institutes in the country actively engaged in developing model curricula and instructional material for all stages of school education. Major initiatives taken by the NCERT are as follows —

- Development of syllabi and textbooks for different stages of school education. The idea of introducing 'Environmental Studies' at the primary stage was conceived by the Council for the first time in 1977 and since then the syllabi and textbooks have been revised during 1987-89 and again during 2001-04. The syllabi and textbooks developed by the NCERT for the upper primary, secondary and higher secondary stages too emphasised on environment and issues and problems relating to them in each exercise undertaken by it since 1977.
- The NCERT has developed Modules for the Pre-service Training by District Institutes of Education and Training (DIET) in the form of four modules, one each for the northern, southern, eastern and western regions of the country.
- All the journals, especially the quarterly journal 'School Science', published by the Council frequently includes articles on topics related to environment and EE.
- The NCERT organises every year Jawaharlal Nehru National Science Exhibition for Children, which is preceded by district and state level exhibitions, and it invariably focuses on environmental problems.
- The NCERT in collaboration with international agencies like

UNESCO, UNICEF, UNEP, World Bank, Commonwealth Secretariat has organised a number of international, regional and national level workshops, seminars, conferences and meetings on various dimensions of EE during the last four decades. The NCERT has also developed pre-service and in-service training modules for school education under contract with UNESCO.

- As per the directives of the Hon' ble Supreme Court, the NCERT has developed a model syllabus on EE for all stages of school education and the same has been published under the title 'Environmental Education in Schools' (June 2004).

Role of NGOs in EE

A number of Non-governmental Organisations (NGOs) in different parts of the country are actively engaged to serve the cause of environment and environmental problems by way of their programmes and activities through direct involvement of school children and general public. In the process many NGOs have developed considerable experience and expertise in formulating and implementing programmes involving research, development and dissemination on various aspects of issues and problems relating to environment and EE.

In the field of environmental education many NGOs have made significant contributions. Notable amongst them are —

- Centre for Environment Education (CEE), Ahmedabad (linked with Nehru Foundation for Development, Ahmedabad),
- CPR Environmental Education Centre (CPREEC), Chennai (linked with Sir C.P. Ramaswamy Aiyar Foundation, Chennai),
- Centre for Ecological Sciences (CES), Bangalore (linked with the Indian Institute of Science, Bangalore),
- Centre for Mining Environment (CME), Dhanbad (linked with Indian School of Mines, Dhanbad),
- Salim Ali Centre for Ornithology and Natural History (SACON), Coimbatore,
- Bombay Natural History Society, Mumbai,
- Centre for Environmental Management of Degraded Ecosystem (CEMDE), Delhi (linked with Department of Environmental Biology, South Delhi Campus, Delhi University),
- The Tropical Botanic Garden and Research Institute (TBGRI), Thiruvananthapuram (linked with the State Government of Kerala),
- Centre of Excellence in Environmental Economics at Madras School of Economics (linked with Madras University, Chennai),
- Foundation for Revitalisation of Local Health Traditions (FRLHT), Bangalore,
- Centre for Science and Environment (CSE), M.B. Road, New Delhi,

- Uttarakhand Sewa Nidhi, Almora,
- The Energy Resources Institute (TERI), Lodi Road, New Delhi.

In order to effectively impart Environmental Education to all sections of the society as envisaged in the NPE - 1986, it is imperative that all agencies, whether governmental or non-governmental, concerned with the promotion of EE should work in close collaboration with each other so as to complement and supplement efforts of each other.

Environmental Education in Other Countries

Environmental Education is now an integral component of school education in almost all countries in the world. However, there are large variations in the form and format of EE, its content and approach in different countries. In a majority of cases, the environmental components have been infused with the curriculum of different subjects of study in schools except at the pre-primary and primary stages where it is taught as a subject in most of the countries. These variations are largely due to the system of education and control mechanisms arising due to differences in prevalent political and administrative structure in different countries. In spite of these variations there are many similarities as may be evident from the brief resume presented here on the salient features of programmes concerning EE in schools of some countries (arranged alphabatically).

China

Environmental Education has been a significant component of education system in China but is not an independent course. The environment-linked topics are offered in natural and social sciences, Chinese language and as extra curriculum. Teachers often make more use of books, newspapers and pictorials rather than video programmes. It is difficult to get good quality books on environment.

Fiji

Environmental Education is not taught as a subject on its own in primary and secondary schools. Instead, environmental education is integrated across the entire school curriculum with every subject area at each class level dealing with environment in some way or the other.

Kenya

To meet challenge of educating the youth, formal environmental education programme has been introduced into Kenya's school curriculum at all levels. Environmental Education is integrated with different subjects of study like geography, agriculture, history and civics, religion and science. In addition to this, pupil are also engaged in carrying out activities that may help to enhance learning of the environment and sensitising them on the matters of the environment.

Malaysia

Environment Education is not taught as a separate subject at the primary and

other stages of school education but components of environment are integrated into relevant subjects such as science, health science, history, geography, and civics. The main objective is to bring about awareness that the man has to live in harmony with the environment in order to ensure their well-being and prosperity.

Norway

Environmental Education is a compulsory part of the syllabus in schools and nursery schools in Norway. The aim of environmental education is to give children and youth knowledge, attitudes and skills so that they can contribute towards sustainable development. It also aims at creating new patterns of behaviour among children and youth through action-oriented environmental tuition.

Starting in nursery school and continuing all through school, children and young people in Norway are taught about nature, environment and development. For this reason, priority has been given to courses and competence building for teachers. Children and young people also become interested in environmental problems through outdoor activities.

Pakistan

The Ministry of Education has initiated action to provide necessary information and skills to combat and contribute towards preservation of resources and improvement of natural environment. Concepts of environment have been incorporated in school textbooks. The curriculum for EE at the secondary level has been developed. Steps necessary to incorporate concepts of EE in relevant subjects in school system have been initiated. Teacher training programmes on a limited basis have also been conducted with the aim of integrating EE in related activities of curriculum/ school programmes as well as curricular activities.

Philippines

The two government agencies, namely the department of education and the Commission for Higher education did not have any specific programmes on EE until 2002. However, they have been providing support through their positive response to activities initiated by other government departments and NGOs. A group of schools have formed the Environmental Education Outreach network. Their programmes involve reaching out to the communities and area outside their schools. Many schools have their own outreach programmes, usually around the school campus. Major work in the field is done by the NGOs.

Republic of Korea

The educational system including the educational curriculum in Korea is centralised. The national educational curriculum prepared by the central government stipulates that the environmental education in elementary and secondary schools should be taught and emphasised through all the activities of the subjects related to the environment. The current national curriculum for EE in the elementary and

secondary schools focuses on consideration of learner's ability, learner's activities and learner's region of everyday life. The contents of environmental educational are scattered in different subjects in elementary schools, and as an independent subject as 'Environment' in middle school and as 'Environment and Ecology' at the high school of the secondary school.

Countries in the European Union

Eleanor Strokes and others of the London School of Economics and Political Science have conducted a study on the status of EE in the school systems of the countries of the European Union (EU) in 2001. The study was commissioned by the Environment Directorate-General of the European Commission. The educational systems of 15 member States of the European Union were covered by the study. Since educational systems in some of the member States is decentralised, more than one systems of education were covered in such cases. These States include Belgium – Flemish and French Communities; Germany – Baveria, North Rhine Westphalia and Thuringia and UK – England, Wales and Northern Ireland and Scotland. Thus, the States/regions that were involved in the study were Austria, Belgium (Belgium Flemish Community and Belgium French Community), Germany (Baveria, North Rhine – Westphalia and Thuringia), Denmark, Spain, Finland, France, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Sweden, UK (England, Wales aand Northern Ireland and Scotland).

The study encompassed various dimensions of EE for different stages of school education as being practiced in the member states. Apart from other issues, it also focussed on the approaches being followed for the teaching learning of EE. According to the study, at the primary level, in 14 out of 19 countries/regions EE is taught as embedded in other subjects, At the lower secondary level EE is taught as embedded in other subjects in 17 countries/regions.

Approaches to EE

We find that curriculum developers have followed two major approaches for teaching learning of EE at school level, namely EE as a separate subject and EE as integrated with different disciplines of study (infusion model). Each approach has its own merits and demerits, some of which are presented below.

Environmental Education as a subject

The introduction of EE as a separate subject, at first sight, might appear to be the easiest option. Seemingly this approach has the following advantages:

(i) The unity and cohesion of environmental issues and concepts is likely to be ensured.

(ii) The EE would have status similar to other subjects, with provision or examinations.

However, EE as a separate subject has some inherent limitations:

(i) Given the nature of EE, many themes and concepts constituting EE may overlap with those in

traditional disciplines. This may result in unnecessary repetitions and curriculum load.

(ii) EE as a separate subject would necessarily require availability of teachers exclusively for EE in schools.

(iii) Availability of teachers with basic qualifications and training in EE is a major problem as only a few institutions in the country offer degree/diploma courses at tertiary level.

(iv) Students may take EE as 'one more addition to the list of subjects of study' and be averse to it from the beginning.

(v) Teachers of other subjects, and the school as a whole, may remain detached. This may hamper reflecting EE concerns through activities of the schools.

Infusion Approach

In Infusion Approach various concepts related to environment are integrated with different subjects of study such as Social Studies, Humanities, Languages, Science, and Mathematics. The major advantages of this approach are:

(i) The environment related concepts can be integrated with relevant specialisations without further increasing the curriculum load.

(ii) The teacher preparation for this model can be managed relatively easily by incorporating a component of EE in both pre-service and in-service teacher preparation programmes.

(iii) The infusion approach provides the requisite scope for the development of desired attitudinal changes as well as skills essential for accomplishing the objectives of EE.

(iv) This approach is perhaps most consistent with definitions, the goals and objectives of EE as perceived by the scientists, educationists and environmentalists.

Although the infusion approach may succeed to a large extent, in creating awareness about issues/concerns of EE, adequate majors need be taken to address to the following disadvantages

(i) Often the focus on environmental issues gets diffused due to emphasis on teaching-learning of the content of the specific subject.

(ii) A majority of environmental concepts cut across different disciplines. Due to this approach the learner may get a fragmented view of the whole concept.

Conclusion

In this paper an attempt has been made to see as to how EE has evolved over the years, different approaches that has been adopted for its implementation in schools in various countries; the development and implementation of EE in schools in India and the challenges that curriculum experts and implementing agencies face today.

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PHYSICS NOBEL FOR 2004

Unravelling the Working of Strong or Colour Force

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ALL MATTER in the universe is made up of quarks and leptons which are structureless and point-like on a scale of 10^{-7} metre. These are the fundamental building blocks of matter discovered so far. The nucleons (protons and neutrons) constituting the atomic nucleus are made up of quarks. The electrons that form the outer casing for atoms are leptons. The atoms join up to form molecules, the molecules build up structures and in this way the whole universe can finally be described.

The theoretical existence of quarks was first predicted by Murry Gell-Mann in 1964. Gell-Mann, however, predicted the existence of only three quarks which were named 'up', 'down' and 'strange'. Charm, bottom and top (or truth) quarks were also discovered subsequently. Thus, we now have a total of six quarks. Each quark has also an anti-particle called anti-quark. The interesting thing about quarks is that in contradistinction to other elementary particles, they carry fractional electrical charges. Up, charm and top quarks carry a positive charge which is two-thirds the electronic charge (+2/3 e) while down, strange and bottom quarks have a negative charge that equals one-third the electronic charge (–1/3 e).

A quality somewhat akin to electric charge that distinguishes otherwise identical quarks is colour. Incidentally, each of the six quarks; come in three coloured – red, blue and green. However, the colour of quarks has nothing to do with ordinary colour (quarks are much smaller than the wavelength of visible light and so they do not have any colour in the normal sense; it is just that modern physicists seem to have more imaginative ways of naming new particles); it represents a special characteristic of quarks called 'colour charge'. In fact, this property of quarks is the source of attraction among quarks. When two or three quarks combine to form a composite particle (proton, neutron, meson, etc.), the particle so formed has no colour which means that it is colour neutral or white. For example, when two up quarks and one down quark combine to form a proton, the total colour charge is white which means that the proton is colour neutral. However, a proton has a net (positive) electric charge which is equal to one electronic charge (2/3 e + 2/3 e – 1/3 e = 1e). Similarly, when two down quarks and one up quark create a neutron, it is also colour neutral; its total electric charge is zero (1/3 e + 1/3 e – 2/3 e = 0) too.

The quarks are bound by a strong force, one of the four basic forces of nature. The Physics Nobel for 2004 has been awarded to David Gross, David Politzer and Frank Wilczek for

Nobel Prize for Physics – 2004

David Pulitzer

David Gross

Frank Wilczek

formulating a theory which explains how the strong force, also called the colour force, works.

Besides strong force, the other three basic forces of nature are gravity, electromagnetic force and weak force. While gravity and electromagnetic force were discovered by physicists long time back, the discovery of weak and strong (nuclear) forces had to await the beginning of the nineteenth century. Of these, the force of gravity is the weakest although it has a big role in shaping our universe. This force is about 10^{40} times weaker than the strong force, 10^{38} times weaker than the electromagnetic force and about 10^{35} times weaker than the weak force.

The force of gravity is mediated by gravitons while the electromagnetic force is mediated by photons. Both these particles are massless. However, the weak force operative between quarks and leptons is mediated by vector boson ($W^{\pm}$ and Z^0). Unlike photons and gravitons they have very large masses (about 100 proton masses). That is the reason why they are also called massive vector bosons.

The strong force between quarks is carried by gluons (from the word 'glue') which, like, photons, are massless. However, like quarks, gluons (which are of eight different kinds) have the property of colour charge. Gluons interact only with themselves and with quarks.

In the beginning we said that the quarks and leptons make up matter in the universe, They are particles of spin 1/2 called férmions. We may note that the spin refers to the internal property of an elementary particle. It actually refers to the "intrinsic" angular momentum possessed by the particle (independent of any orbital angular momentum it might have). One could crudely compare this situation with the Earth moving in its orbit around the Sun. Besides possessing orbital angular momentum as a result of its motion around the Sun, the Earth also spins about an axis passing through the poles, thereby possessing spin angular momentum. However, this is a very crude

analogy. Quantum mechanically, the situation is not that simple.

Besides spin 1/2 particles we also have particle of integral spin (including zero), called bosons, they give rise to forces between matter particles (fermions). Photons, W^+ , W^- , Z^0 vector bosons and gluons, which are all spin 1 particles (a particle with spin 1 was earlier designated as a vector particle; this name is now redundant although it is still in vogue), are boson. Helium (He^4) atoms having spin 0 are also bosons. Gravitons, the spin 2 particles, are bosons too. Interestingly, an $\propto$ particle (helium nucleus), composed of two protons and two neutrons, also behaves like a boson. The general rule is that a composite particle is a fermion or boson depending on whether it contains an odd or even number of fermions. Interestingly, physicists are fond of using such phrases as bosons show 'social' behaviour while the fermions show 'anti-social' behaviour. The so-called anti-social behaviour of fermions stems from the Pauli's exclusion principle according to which no two fermions can exist in the same quantum state. As a result, the two fermions keep aloof from each other.

The three forces (particle physicists often prefer to use the work 'interaction' instead of the word 'force') that are applicable to microcosmos or the sub-atomic world are the electromagnetic force, weak force and the strong force. They are described by the Standard Model. The particle physicists use gauge theories to describe various interactions. Using a special gauge theory Sheldon Glashow, Abdus Salam and Steven Wienberg were able to unite the weak and the electromagnetic forces into a single electro-weak interaction. For this phenomenal work the trio was awarded the 1979 Nobel Prize in Physics. However, this theory had some shortcomings. The final formulation of the theory (which is a non-abelian gauge theory based on the concept of renormalisation) came from Martinus Veltman and Gerardus't Hooft who were honoured with the Physics Nobel Prize in 1999.

The physicists were also venturing hard to formulate a theory explaining the strong force or colour force. But, the formulation of such a theory was posing lots of difficulties. The greatest difficulty the physicists were facing was regarding the nature of quarks. Of course, it had been known since the 1960s that the constituents of nuclei, protons, and neutrons, are built of quarks. But, all attempts of physicists to produce free quarks failed miserably. This led them to conclude that quarks cannot exist freely. Only aggregates of two or three quarks forming composite particles (e.g., proton, neutron, meson, etc.) can exist freely.

Generally, all forces become stronger at short distances. Such forces are said to have positive coupling constant. But, this no longer holds true for strong force that goes systematically weaker as the separation between the particles (quarks) gets smaller. For example, at higher energies when quarks come closer, the interaction strength between them decreases. On the other hand, at lower energies when quarks get farther apart, their influence on each other gets stronger instead of weaker. This means that the interaction strength increases

with increasing distance. A force having such characteristics is said to have negative coupling constant (or, as physicists sometimes prefer to call it, negative **beta function**). Such a force has a property called **asymptotic freedom**. Literally, 'asymptote' means getting things close. However, in mathematics or physics, this word has a different significance. 'Asymtote' means in the limit that there is no separation (try to recapitulate a curve or a function that approaches infinity asymptomatically). Thus, when high-energy quarks come close together the force that binds them strangely slackens. Conversely, when quarks move apart, the force becomes stronger, as if the bond is rubber band — the more it stretches, the stronger the force.

For a long time physicists had been looking for a theory by which the effects of the strong interaction could be calculated in the same way as for electromagnetic or the weak interaction. The German theoretical physicist Kurt Symanzik and Curtis Callen, Jr. of the Institute of Advanced Study, Hamburg tried to evolve a theory for strong interaction but they failed in their attempt. It may be mentioned that Gerardus's Hooft came very close to discovering such a theory. But, success was finally achieved by David Gross and Frank Wilczek and independently by David Politzer. In 1973, two papers unravelling the theory for strong or colour force were published in the US journal **Physical Review Letters**, one by Gross and Wilczek and the other by Politzer. The papers of the Nobel Laureates described an **asymtomatically free** theory for strong interaction that is characterised by negative coupling constant. A more complete name for this theory is Quantum Chromo-Dynamics (QCD) in analogy with the theory for the electromagnetic interaction called Quantum ElectroDynamics (QED).

Although quarks do not act as free particles but when protons are bombarded at very high energies, quarks behave as almost free particles. The calculations made from the theory formulated by the Nobel Laureates showed excellent agreement with experiments. This provided a firm foundation to their theory.

Theoretically, in the limit that quark separation goes to zero, quarks become free particles. But, in this limit as no force acts between them they do not feel the presence of each other. However, the interaction between them starts manifesting as soon as they are pulled apart so that the distance between them becomes non-zero.

The formulation of a theory for strong or colour force seems to be one step forward towards constructing a unified 'theory of everything'. The quest for such a theory, that ropes in all the four basic forces of Nature, is known as the unification of forces. It may be mentioned that the search for unification of forces is a great passion with physicists. Einstein spent most of his later years trying to unify gravity with the electromagnetic force but he did not succeed. Although Einstein failed, his quest for unification has inspired many a physicist. Glashow, Salam and

Weinberg, as already mentioned, showed that the weak and the electromagnetic forces could be unified into a single force called electro-weak force. The predictions of their theory have been verified by experiments requiring the use of very high-energy accelerators. It seems that in order to unify gravity with other forces of Nature, a quantum theory of gravity is needed. Physicists are already working on such a theory, called string theory. As realised by physicists, some modifications in the Standard Model, say, by way of inclusion of supersymmetric particles etc. would be needed if the dream of the unification of the forces of Nature is to be finally realised.

Notwithstanding various developments in the field of unification one thing is certainly clear that the work of the Nobel Laureates has paved the way for a possible unification of strong force with the electro-weak force. Such a unification will certainly be realised in future, hope the physicists.

Organometallic Polymers

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POLYMERS are high molecular weight compound utilised mostly in polymer industries for its production of wide range of articles. There is virtually no industry that does not make use of polymer and polymeric products in their production. These polymeric substances can be modified by addition of certain substances (additives) to enhance their properties. One of such additives is the organometallic compound.

Organometallic compounds are certain class of organic compounds that contain at least one-metal-carbon bond. These compounds have unique properties that set them apart from both the organic and inorganic compounds.

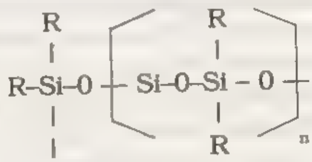
Organometallic polymers is a class of polymers in which the metal-containing portion is either incorporated as integral part of the polymer or bound to the polymer structure by covalent bonds (Carraher et al; 1977)

Classification of Organometallic Polymer

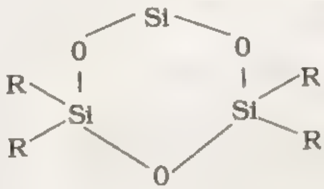
The different classes of organometallic polymers include:

Organosilicon polymers known as silicones, the silicones are polymeric organosilicon compound containing Si-O -Si linkages and Si-carbon bonds. These polymers are very stable because of the presence of strong silicon oxygen and silicon-carbon bond. Both carbon and silicon are known for their strong properties of catenation. Catenation is the property of an element to be able to form long chain compounds e.g. carbon-hydrocarbons and silicone-silanes.

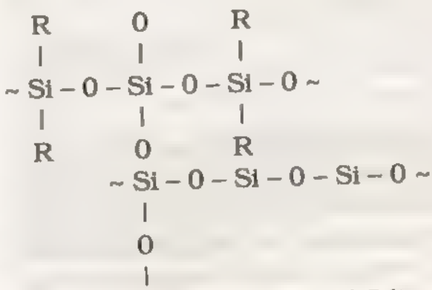
The general formula of the silicones is $(R_2\,S_i\,O)_x$ where R can be a variety of organic group and x the number of the chains. The silicones may be linear, cyclic or crosslinked pylons (Safra et al; 1976)



Linear Silicone



Cyclic Silicone

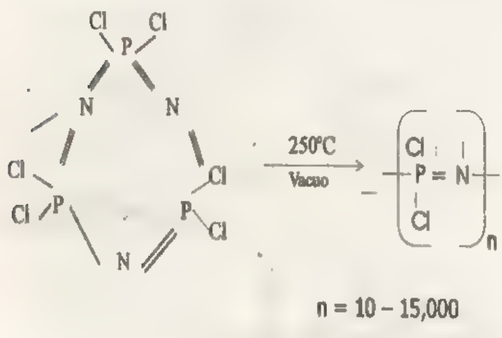


Cross linked Silicones

Silicone polymers incorporate both the properties of carbon-hydrogen and silicone-oxygen compounds. As a result they are stable to many chemicals and heat. Depending on the molecular weight, degree of polymerisation, and complexity of the attached groups, silicon polymers can occur in the forms of oils, greases, waxes and rubber-link substances of resin (Safra et al; 1976).

Organophosphazenes polymers: These are organometallic polymers which contain phosphorus and nitrogen which can occur as dimers, trimers, tetramers or the high molecular weight polymers known as the organophospazenes.

Stable polyorganophosphazenes can be prepared by the melt ring opening polymerisation of hexa chlorotriphosphazene (trimer) followed by the reaction of soluble polydichloro phosphazene with various organo nucleophiles e.g.



This is cross linked inorganic rubber. Polyphosphazene are found to have characteristically high molecular weight, and broad molecular weight distribution (MWD). Their average chain structure and solubility characteristics depend on the degree of polymerisation as well as the functionality of the polymer chain side group (Drydson 1979).

Polymeric sculpture Nitride (SN)x: Sulphur can be made to polymerise with nitrogen to long chain compounds known as polymeric sulphur nitrides. Polymeric sulphur nitride is prepared conveniently in the form of lustrous, golden monoclinic crystals of disulphur dinitride S_2N_2 at room temperature. It may also be prepared in the form of golden epitaxial films in which the (SN)x polymer chains are aligned parallel to each other. This Polymer has electrical and optical properties characteristics of an anisotropic metal chelali. The metallic properties being more pronounced along the direction of the (SN)x polymer chain than in directions perpendicular to the chain.

During the solid state polymerisation of S_2N_2 crystals at room temperature, the crystals will first become dark blue-black paramagnetic in nature before changing into lustrous golden diamagnetic (SN)x crystals. The bonding between sulphur and nitrogen atoms in an (SN)x chain may be considered a derived to a first approximation from the extreme resonance forms

- S-N=S=N-S-N=S=N– ↔ S=N-S-N=S=N-S-N=
-S = N-S-N = S = N-S-N = ↔

In which all atoms exhibit normal oxidation state and valences. These give rise to the resonance hybrid species.

≕ S ⩦ N S ⩦ N ⩦ S ⩦ N ⩦

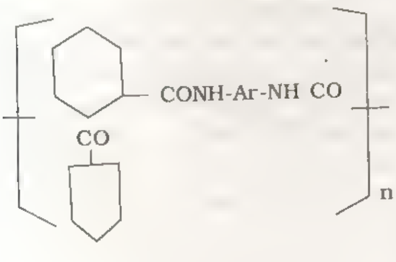
In which all bonds are intermediate between double and single bonds. Also the reaction of the (SN)x with bromine gives rise to new series of polymeric metal – the polythiazyl bromide.

Organometallic Condensation Polymers

Organometallic polymers formed by condensation reaction using the interfacial or solution polymerisation techniques are called organometallic condensation polymers. In most cases the interfacial polymerisation technique is preferred to other condensation methods because it is often more favourable thermodynamic system usually capable of generating products from less reactive co-reactants compounds than with solution technique.

Polyesters of Cobalticinium 1,1 – Dicarboxylic Acid

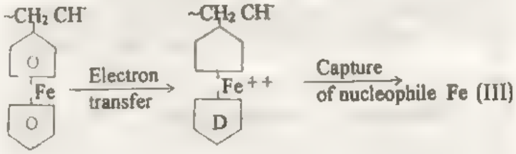
This organometallic polymer is readily prepared by permanganate oxidation of 1/1- dimethyl cobalt salts which can be converted to the acid chloride and esters. When solutions of the acid chloride in acetonitrile is added to solution of 1,4- butanediol and of 1,4 bis hydroxy methyl benzene low molecular weight polymers are obtained (Sheats, 1970). Other forms of condensation organometallic polymers are Poly (cobalticinium carboxamide) and lead (iv) polyesters.



Organometallic Addition Polymers

These are organometallic polymers resulting from chain reactions involving some active centres (free radicals or ions)

A typical example is polyvinyl ferrocMe obtained from the polymerisation of vinyl ferrocene using Ziegler-Natta initiators.

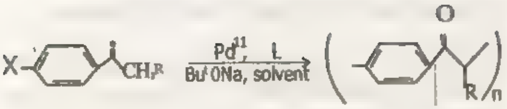


Ferrocene nucleus participates in radical polymerisation and this is example of intramolecular electron transfer termination of polymerisation reaction.

$$\sim CH2 - CH\,(FC) \rightarrow 2\,CH_2 \sim CH_2\,(FC^{+})$$

(Fc is the ferrocenyl group (C_{10} Hq Fe.) and the " polymer chain contain an ionically bound high spin ($3d^5$) complex of Fe 3^+ ion (Carraher et al, 1977).

Also poly(p-Phenylene-vinylene) PPV can be polymerised using palladium complexes as catalysts. Palladium complexes have been used to catalysts the condensation polymerisation of halophenyl alkyl ketones to form polyketones. These polyketones can be readily converted to (poly (phenylene vinylene) and its derivatives (Wang and Wu, 1999). Halophenyl alkyl ketones can readily undergo condensation polymerisation in the presence of a catalytic amount of Palladium complex as base and phosphine ligands.



R = H, alkyl group
X = Br, I
L = phosphine

The influence of halogen, alkyl subsitutent on the polymerisation of 4-halophenyl ketone with palladium has been reported (Wang and Wu, 1999) with longer alkyl substituents were used, polymers with higher molecular weights were obtatined from it after fractional precipitation.

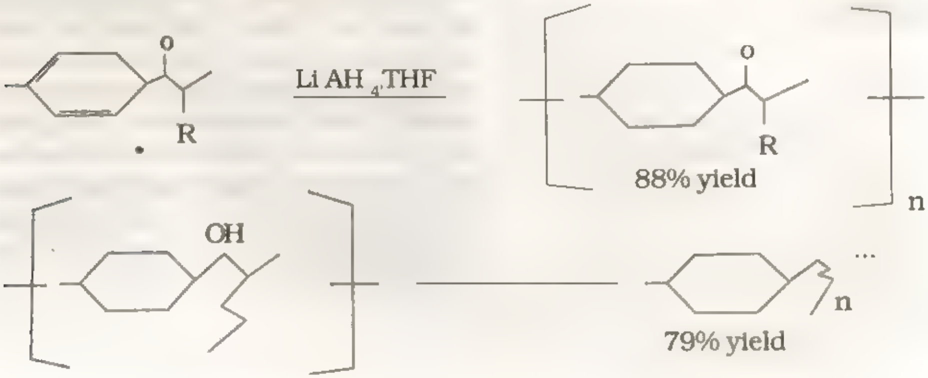
The study also showed that' the solvent used in the polymerisation reaction also affect the rate of polymerisation and hence the yield. Poler solvents seem to enhance the rate of polymerisation eg. polymers prepared using a catalytic amount of Pd. $(oAc)_2$

Halogen X	**Alkyl group R**	**Yield %**	**Molecular weight**	
			$\bar{M}_n \times 10^6$	$\bar{M}_w \times 10^6$
Br	H	60	18.0	25.0
I	H	76	–	–
Br	Me	70	17.0	21.0
Br	Bu	90	32.0	41.0
I	Pr	65	101.0	132.0

Pr-Propyl, Me = methly, Bu = butyl groups

Polymerisation of 4-hatophenyl ketones

The alkyl substituent can dramatically enhance the yield of polymers e.g. when the substituent is hydrogen (H), the polymers are obtained in low yield whereas when monomers ligand exhibit higher molecular weight on tetrahydrofuran (THF) than in other solvent. Better yield of polymers were also obtained in solvent such as orthodichlorophenylene and benzene.



...(1)

...(2)

No polymerisation was observed when dimethyl acetone (DMA) was used in solvent which may be attributed to deactivation of the catalyst used (Wang and Wu, 1999).

The carbonyl group in the polymers can be quantitatively converted to the hydroxyl group using L_i Al H_4 equation (1).

In order to obtain the P-Phenylenevinylene (PPV) derivative, the product in equation (1) was further treated with a H_3PO_4 ip toluene leading to rapid elimination of water (H_2O) molecule to yield the polymer in equation (2) which was soluble in common organic solvents as THF and dichloromethane CH_2 Cl_2. (Wang and Wu, 1999).

Some other organometallic polymers and their sythesis have been reported in literature (Rao et al; 1999 prime et al; 1999).

Characteristics of Organometallic Polymers

Organometallic polymers are soluble in fewer solvents. The poor solubility may be due to factors such as highly cohesive forces between the chains, highly crystalline nature of these polymers and a peculiar bonding of both non-polar and low to high polar contributions.

Organic polymers modified utilising organometallic monomers are generally rubbery with the formation of tough films made possible from linear products.

They are hydrophobic and resistant to hydrolysis. Melting (Tg and Tm) may or may not occur prior to initial degradation depending on the polymers. Organometallic polymers have high resistivities (10^4–10^{10} or $m^{-11}cm^{-1}$) and are thus good semi-conduction in most electronics.

Application of Organometallics Polymers

Potentials application of organometallics polymers include use as adhesives, antifouling agents in paints, bactericide biopolymers catalysts and as implants in living tissues.

The biomedical use of the organometallic polymers can be seen in the case of platinum containing organometallic polymers which are water soluble used as anti cancer agents. They consist of the water soluble polymeric end while the aminoacid ester end substituted with polyphosphazene are designed to degrade hydrolytically to aminoacid phosphate, alcohol and ammonia which are excreted out of the body of the patient (Carraher, et al. 1977). Typical example of biomedical organometailics are poly organophosphazenes, hydrophobic polyfluoro alkyl oxyphosphazene and poly (ammo acid ester phosphazene) organometallic polymers are promising materials for nonlinear optics.

Poly (p-phenylene vinylene) PPV and its derivatives have attractive properties such as non $\rightarrow$ linear optical response, photo and electroluminescence with good electrical conductivity. (Archer, 2001)

Their advantages are high and fast optical nonlinearities, small linear and two-photon absorption.

Organometallic polymers such as films of poly (ethyne diyl-arylene ethynediyl-silylene) and bis (arene)

chromium containing polyacrylonitrile have high electron optical susceptibility very useful in non — linear optics. These polymers can be used for the creation of fast optical switchers because of small activation time for electron optical non linearity used in interferometers. (Archer, 2001).

Organometallic polymers can also be used as catalysts to produce high density linear polyethene (HDPE) and other etheneolefin copolymers.

Other industrial uses of organometallic polymers are as UV- stabilizers and thus inclusion of these class of polymers in paint mixtures impart stability for outdoor application of paints and offers better weatherability regarding UV photo stability. Also antifungal, antibacterial compounds contain organometallic compounds of this which serves as rot, mildew resistance in rug carpets, clothings (Mc Henry 1976). Both ferrocene and Cobalticinium moieties of organometallic polymers can be bound to proteins. Thus polymers (modified natural or synthetic) containing these moieties might offer useful biological activities in living things. Polymers containing tin or arsenic coupled with sugars, purines, pyrimidines etc might also offer useful (controlled release) biological activities.

Titanium-containing polymers give rise to fibre which offer good weight retention with some dimensional stability.

Other uses of organometallic polymers include photosensitive media in photocopying devices, adhesives, flame retardants, electrically conductive and semi-conductive devices applications.

In summary, organometallic polymers have novel application in science and technology.

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Cell Regulation of Unwanted Proteins and Mysteries of the Sense of Smell Unravelled

(Nobel Prize in Chemistry and Physiology and Medicine for 2004)

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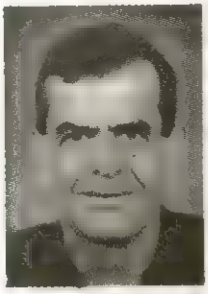
A HUMAN cell contains some hundred thousand different proteins. Besides being responsible for the cell's form and structure, the proteins have numerous other functions, too. They can, for example, act as accelerators of chemical reactions in the form of enzymes, as signal substances in the form of hormones, as important actors in he immune defence, and so on. But, not all proteins have a positive role, some are unwanted, too. The cells possess a regulatory mechanism by which such unwanted proteins may be eliminated or destroyed. It is for this discovery of protein-regulating system that two Israelis, Aaron Ciechanover and Avram Hershko and Irwin Rose, an American, have been jointly awarded the 2004 Nobel Prize in Chemistry.

While great attention had been focussed and much research work devoted to understanding how the cell controls the synthesis of a certain protein (at least five Nobel prizes have so far been awarded in this area), the degradation of proteins has long been considered less important. Although some enzymes were known which could destroy proteins, it was found that they do not require any energy in order to function. However, breakdown of the cell's own proteins does need energy. This, for long, puzzled the researchers and it is precisely this paradox that underlies this year's Nobel Prize in Chemistry: that the breakdown of proteins within the cell requires energy while other protein degradation takes place without added energy.

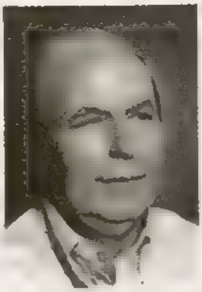
The three Nobel Laureates in Chemistry, through a series of biochemical studies made in the late 1970s and 1980s, succeeded in showing that protein degradation in cells takes place in a series of step-wise reactions that result in the proteins to be destroyed being labelled with a 76-aminoacid-long polypeptide. This molecule was named ubiquitin (from Latin 'ubique' meaning everywhere) as it occurs in numerous tissues and organisms (barring, of course, bacteria).

As soon as a protein to be destroyed gets the ubiquitin label, or tag, it receives, so to say, the 'kiss of death'; it then gets marked for final destruction. The specific enzyme that determines which proteins in the cell are to be marked for destruction is designated as the E3 enzyme. The entire process of labelling and destruction of the unwanted proteins in the cellular 'waste disposers' called proteasomes takes place in a number of steps with the help of E1, E2 and E3

Nobel Prize Chemistry – 2004



Aaron Ciechanover



Avram Hershko

Irwin Rose

enzymes. In fact, it is the E1 enzyme that activates the ubiquitin molecule. This reaction requires energy in the form of ATP (Adenosine Tri Phosphate), which is cell's energy currency. The activated ubiquitin molecule is transferred to E2 enzyme resulting into the formation of the E2-ubiquitin complex. The target protein to be destroyed is recognised by the enzyme E3. The E2-ubiquitin label can be transferred from E2 to the target. The E3 enzyme now releases the ubiquitin-labelled protein. This step is repeated until the protein is in the form of a short chain of ubiquitin molecules attached to itself. This ubiquitin chain is recognised in the opening of the proteasome. The ubiquitin label is disconnected and the target protein is finally admitted and chopped into small pieces. In this way the protein that received the death warrant by way of 'kiss of death' meets its inevitable end.

The results of the work done by the three Nobel Laureates show that cells really break down faulty proteins using the ubiquitin system. We now know that up to 30 per cent of the newly-synthesised proteins in a cell are broken down via the proteasomes since they do not pass the cell's rigorous quality control.

The work of the three Laureates has made it possible to understand at molecular level how the cell controls a number of very important biochemical processes by breaking down certain proteins and not others. Examples of such processes are the cell division, DNA repair, gene transcription, quality control of newly-produced proteins, and important parts of the immune defence. Defects in the system can lead to various diseases, including cervical cancer and cystic fibrosis. A malfunctioning system may also result into miscarriages in women. The work of the Laureates might help introduce new medicines that can fight cancer and a host of other diseases.

Of the three Nobel Laureates, Ciechanover, 57, is director of the Rappaport Family Institute for Research in Medical Sciences in Hafia, Israel, while Hershko, 67, originally from Hungary, is a professor there. Rose, 78,

is a specialist at the Department of Physiology and Biophysics at the college of medicine at the University of California, Irvine. He is also a member of the US National Academy of Sciences. All three will share the 10 million kroner ($1.3 millions) cash prize.

Work on the sense of smell: Nobel Prize in Physiology and Medicine 2004

The smell of a rose is never confused with the smell of any other smell. Also, it can be recalled even years later. The same holds true for any other smell; for instance, the smell of the soil immediately after a rain. The human sense of smell is very special indeed; losing it would mean a series handicap. We will no longer be able to detect the warning signals, for example, smoke from a fire. How, after all, our olfactory system works? The 2004 Nobel Prize in Physiology or Medicine has been jointly awarded to two Americans, Richard Alex and Linda B. Buck, for unraveling the mysteries of our sense of smell. The

Nobel Prize Medicine – 2004

Richard Alex

Linda B. Buck

Laureates discovered a family of about 1000 genes (which is roughly three per cent of our genes) that give rise to an equivalent number of olfactory receptor types. These receptors are located on the olfactory receptor cells, which occupy a small area in the upper part of the nasal epithelium and detect the inhaled odorant molecules. Alex and Buck independently found that each olfactory receptor cell only expresses one single odorant receptor gene. Thus, there are as many types of olfactory receptor cells as there are odorant receptors. Each odorant receptor consists of a chain of amino acids that is anchored into the cell membrane. The chain creates a binding pocket where the odorant can attach.

When an odorant receptor is activated by an odorous substance, an electric signal is triggered in the olfactory receptor cell which is sent to the brain via nerve processes. Actually, the olfactory receptor cell sends its nerve processes to the olfactory bulb, the primary olfactory area of the brain. Present in the olfactory bulb are some 2000 well-defined micro regions or domains called glomeruli. Receptor cells carrying the same type of receptor send their nerve processes to the same glomerulus. Found in the glomeruli are not only the nerve processes from the olfactory receptor cells but also their contacts with the next level of nerve cells, the mitral cells. Each mitral cell is activated only by one glomerulus. Via long nerve processes the mitral cells relay the information to several parts of the brain. These nerve signals in turn reach defined micro regions in the brain cortex where the information from several

types of odorant receptors is combined into a pattern characteristic for each odour. Thanks to our dedicated olfactory system, we are able to recognise and remember, believe it or not, about 10,000 different odours.

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Constructivism : A New Perspective in Teaching Science

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Socrates tried to lead students through a series of questions in order to promote critical thinking. Today, his questioning approach is often hailed as an effective teaching technique. The needs of the emerging knowledge society necessitates the development of personal competencies such as the abilities to be self starting, quick thinking, problem solving, risk taking individuals who can operate in collaborative situations. Unfortunately it is not happening in the traditional epistemological paradigm. In last six decades pedagogy has been dominated by the behaviouristic model. In behaviourist approach, the teacher's task consists of providing a set of stimuli and reinforcements to emit desired responses. It is based on S-R (Stimulus-Response) theory, leading to desired and observable behaviour. If the objective is that students replicate a certain behaviour, this method works well, but if we want to develop understanding, synthesis, eventual application, and the ability to use information in new situations, a behaviourist approach is not useful. Because, there is no place in the model for understanding. Cognitive scientists support Constructistic View of Learning. Todays cognitive research focuses more on students than teachers. Learning is an active process occurring within, and influenced by the learner as much as by the teacher and the social context where learning is taking place. From this perspective, learning does not depend on what the teacher presents. Rather, it is an interactive process, how the student processes knowledge, based upon the existing personal knowledge. All learning is dependent on language and communication. It reflects an alternative theory of knowing-cognitive constructivism. Knowledge, its nature, and how we come to know, are essential considerations for constructivists.

What is Constructivism?

Constructivism is a philosophy of learning founded on the premise that by reflecting on our experiences, we construct our own understanding of the world we live in. Each of us generates our own 'rules' and 'mental models', which we make from our experiences. Learning, therefore, is simply the process of our mental models to accommodate new experiences. Glasersfeld (1995) describes it as a 'theory of knowledge with roots in philosophy, psychology and cybernatics'. In the constructivist perspective, knowledge is constructed by the individual through his interactions with his environment. If we believe that learners actively construct knowledge to make sense of their world, then learning will likely emphasise the development of meaning and understanding.

'Constructivism is a theory that assumes knowledge cannot exist outside the bodies of cognising beings ... knowledge is a construction of reality'.

Historical Perspective

It is true that constructivist theory has reached high popularity in recent years, but the idea of constructivism is not new. Some of the aspects of constructivist theory can be found in the works of Socrates and Plato. But the main philosophy of constructivism is credited to Jean Piaget. Piaget's ideas are summed up as, 'knowledge is actively constructed by the learner, not passively received from the environment'. In this approach, the prior knowledge of the learner is essential to be able to 'actively' construct new knowledge. Constructivism stems from cognitive psychology, especially the writings of Piaget, Dewey, Vygotsky, Glasersfeld and others. Martin (1998) has very aptly presented different types of constructivism which are as follows:

'Personal constructivism has been initiated by Piaget which contributes, 'knowledge is actively constructed by the learner, not passively received from the environment.' Glasersfeld has called it as Trivial Constructivism.

Radical constructivism was initiated by Glasersfeld which speaks, 'coming to know is a process of dynamic adaptation towards viable interpretations of experience. The knower does not discover truth about the real world.

Social constructivism has been outlined by Vygotsky as well as Dewey which narrates that individuals participate in the learning of a collective, sometimes with what is learned distributed throughout the collective more than in the mind of any one individual.

Cultural constructivism represents the ways in which individuals think, are affected by the cultural influence which is beyond the immediate social environment of a learning situation.

Critical constructivism looks at constructivism within a social and cultural environment, but adds a critical dimension aimed at reforming these environments in order to improve the success of constructivism applied as a referent.

Meaning of the Constructivistic View in Science Education

Duiet (2000) has very aptly mentioned that the constructivist view primarily presents a particular way of conceptualising knowledge and knowledge acquisition, that is, learning. It is a view of the nature of knowledge and its development. It is based on a certain epistemology, that is, theory of knowledge.

The constructivistic view comes in many variables in Science Education on students' learning but it shares a common 'constructivst core'.

The common constructivist core is a view of human knowledge as a process of personal cognitive construction, undertaken by the individual who is trying, for whatever purpose, to make sense of his/her social or natural environment.' In other words, knowledge is not viewed as some sort of a true copy

of features of the world outside but as construction of the individual knowledge acquisition, that is, learning. It is not transfer of knowledge to the individual but a personal construction by the individual. The learner is not seen as a passive receiver but as an active constructor of knowledge.

In science education, Glasersfeld's radical constructivism is generally used as a reference point of the constructivist view. Radical constructivism is an epistemology, a theory of knowledge, more precisely a theory of 'experiential' knowledge. This knowledge is seen as tentative human construction on the basis of already existing knowledge. The tentative character of experiential knowledge reflects that there is any kind of ultimate truth for this kind of knowledge. The character concerns every kind of experiential knowledge, knowledge constructed by the individual and science knowledge as well. There are three key principles of radical constructivism (Duit,1998).

1. The first principle is: knowledge is not passively received but is constructed by the cognising subject.
2. The second principle states that the function of cognition is adapti ve and enables the learners to construct viable explanations of experiences. Knowledge of the world outside, hence, is viewed as human tentative construction.
3. The third principle highlights that although individuals have to construct their own meaning of a new phenomenon or idea, the process of constructing meaning always is embedded within a social setting of which the individual is part.

The Common Core of the Constructivistic View as used in the Science Classrooms

Science teachers understand,that knowledge cannot simply be transferred verbally without understanding about meaning and experiential base. Knowledge is not acquired passively. Constructivist teachers of science promote group learning where two or three students discuss, approaches to a given problem. Science teachers consider students' prior knowledge as the starting point, they are encouraged to reflect on their understandings and test and if necessary modify these in the light of new evidences. The classroom structure encourages the exchange of ideas. The process in each case is fundamentally social.

1. Students are encouraged to actively engage with ideas and evidence. The student creates new understanding for himself. The teacher allows to experiment and students participate in hands-on activities.
2. Students are challenged to develop meaningful understandings.
3. In a constructivistic classroom, learning is constructed. Students come to learning situations with already formulated knowledge, ideas, understanding. This previous knowledge is the raw material for

the new knowledge they will create. Teachers allow students to reflect and to construct their own learning.

4. Students control their own learning process and they proceed by reflecting on their experiences. The teacher helps create situations, where students feel safe. The teacher should also create activities that lead the students to reflect on his prior knowledge and experiences.
5. Constructivistic view of learning is inquiry based. The main activity in the classroom is problem solving. Students use inquiry methods to ask questions, investigating a topic, and use a variety of resources to find solutions.
6. All ideas or knowledge by the individual are tentative in nature. Also science knowledge as acceped in scientific community today, in principle. is tentative in nature and open for revision (Duit, 1998).
7. Science is linked with students' lives and interests.

Practices Associated with Constructivist Teacher in Teaching Science

The philosophy of constructivism has been discussed by many philosophers and psychologists. But classroom teachers need clarification on impact of constructivism on pedagogy and implications of constructivism on classroom practice. Here, we will try to explore what 'best practices' are associated with a constructivist teacher and how we can use them in the classroom.

In 1991, Wheatly proposed a model of constructivst teaching using the problem centered learning approach. This approach has three components. Tasks. groups and sharing. Wheately (1991) has suggested that in preparing for a class a teacher selects tasks which have a high probability of being problematical for students tasks, which may cause students to find a problem. Secondly, the students work on these tasks in small groups. During this time, the teacher attempts to convey collaborative work as a goal. Finally, the class is convened as a whole for a time of sharing. Wheatly believes that 'each students will build his own conceptual structures'. Wheatley's problem centered approach to learning is a simple and open ended approach.

There are many variants of constructivism having earned a place in science education that has improved teaching and learning in science. The contemporary constructivism is a part of student centred pedagogy of science teaching and learning. If we are eager 'to prepare a responsible and reflective citizen, that is, a person who is able to a certain extent to understand basic features of science concepts and ideas that will deeply influence the life in the 21st century then the deep understanding of science, as underlying the constructivistic view of learning is a must so to speak. This understanding, namely, includes deep and applicable knowledge of science content, insight into the role of science contents in technology and society (including issues

of environmental concern) as well as comprehension of the nature of science knowledge (adequate, philosophy of science views) (Duit,2000).

Constructivism Inspired Pedagogy

The aim of constructivistic science instruction are fundamentally different than conventional approaches. Constructivist view of learning is student centred. Understanding science is a part of constructivist approach which is far beyond to memorisation of science facts. It also includes application of science knowledge. Schooling has to give every student the confidence and ability to manage their own learning as an on going life long activity. Schools, therefore, have to start a dynamic process through which pupils are progressively weaned from their dependence on teachers and institution.

Cognitive psychology has provided a basis for constructivistic teaching. Piaget (1971) was one of the early contributors. He suggested that new experiences are received through existing knowledge, a process of assimilation and accommodation. Learners construct knowledge as they attempt to bring meaning to their experiences. Glasersfeld (1995) was another contributor of constructivistic research. He explains that constructivism is a theory of rational knowing. Learners construct knowledge themselves. Sundra J. Moussiax and John T. Nonnan (1998) have observed that constructivistic teaching emphasises thinking, understanding, reasoning and applying knowledge while it does not neglect basic skills. It is based on the idea that reamers construct their own knowledge, rather than reproduce someone else's knowledge.

In a constructivistic classroom, the teacher is no longer a transmitter of knowledge. The science teacher is a facilitator of knowledge construction. Thus, a science teacher functions as a facilitator of learning. As a facilitator he/she understands that learning is related to the learners' previous knowledge, current interest, and level of involvement.

Tolman and Hardy (1995) have observed that constructivistic teaching is guided by five basic elements: (1) activating prior knowledge, (2) acquiring knowledge, (3) under-standing knowledge, (4) Using knowledge, and (5) reflecting on knowledge.

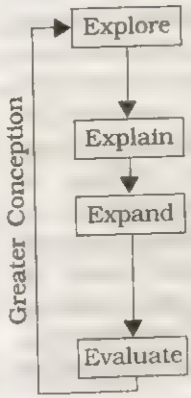
From a constructivistic perspective, learners construct knowledge as they attempt to bring meaning to their experiences. Glasersfeld (1995) has explained that constructivism is a theory of rational knowing. Learners construct knowledge themselves on the basis of subjective experiences. Learning takes place within the cognitive domain of the individual. In this context, teaching is taken as a purposeful, designed intervention into the process of learning through knowledge construction. Teaching reflects interrelationship between people. This revolves round the active construction of conceptual structures, which mediate between the learner, and his/her live experience (Glasersfeld, 1993). The teacher attempts to be a significant part of learners' live experience. Constructivist science

teachers are the intermediate agents between learners and curriculum. Some of the procedures used by science teachers include (Mike Watts et al, 1998, Yager, 1991) :

- Place the focus on learner,
- Using student questions and ideas to guide instructional units.
- Accepting and encouraging student initiation of ideas,
- Interact with learner closely in order to enhance social interactions.
- Encouraging the use of alternative sources for information both written material and experts,
- Encouraging students to suggest causes and for events and situations.
- Encourage students to test their own ideas.
- Using cooperative learning strategies that emphasise collaboration, respect individually.
- Encouraging self analysis and reformulation of ideas in the light of new experiences and evidence.
- Take a variety of roles in order to monitor and evaluate learning, and
- Encourage a plural, tentative and contingent view of scientific knowledge.

Martin et al (1994) have evolved a constructivist learning and teaching model:

Teacher's Activity



Provide opportunities for students to explore through all senses.

Interact with students to discover their ideas.

Help children develop their ideas through additional physical and mental activities.

Evaluate conception by examining changes in children's ideas and their mastery of science process skills.

Going beyond Constructivism

Andre Giordan (1997 and 1999) has raised some questions concerning the inadequacy of the constructivistic view of learning. He has observed that the conditions facilitating learning, or the efficient pedagogical strategies remains very crude. Similarly, the various cosntructivistic models say nothing about the context or parameters of learning, and provide few applications for situations favouring it. Constructivstic models remain highly influenced by the idea of maturation'. Students learn following a chronology relating to a succession of development stages, and this chronology still remains nearly impermeable to processes that facilitate learning.

Learning includes an ensemble of multiple and valued activities. Learning mobilises several disperate levels of mental organisation, as well as a considerable number of regulatory loops. There is a need of supportive environment whicp facilitates learning. There seems to be little evidence to identify and use such environment.

There is a need for further research to strengthen constructivism by providing specific theoretical ideas as well as methodological parameters. There is a need for concrete analysis of processes and activities that exist in the background of knowledge construction. It will provide new ideas on: How students' active engagement, meaningful learning and knowledge advancement could be facilitated. Can we trace tenets of constructivism in the educational philosophy of Mahatma Gandhi, popularly known as the Basic Education? Can we try to study the Gurukul System of education which was prevalent in ancient India? This system was based on question-answer approach, it was learner centred, interactive process.

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Student's Understanding of Balancing Chemical Equations: A Constructivist Approach

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Until recently the accepted model for instruction was based on the hidden assumption that knowledge can be transformed intact from the mind of the teacher to the mind of the learner. Educators therefore focused on trasferring knowledge to their students, and educational researchers tried to find better ways of doing this. Unfortunately all too many of us who teach for a living have uncovered evidence for the following hypothesis. 'Teaching and learning are not synonymous; we teach; and teach well; without having the students learn'. Most cognitive scientists now believe in a constructivist model of knowledge (Resnick; 1983 ; Bodner; 2001) that attempts to answer the primary question of epistemology, 'How do we come to know what we know?'. This construc-tivist model can be summarised in a single statement; Knowledge is constructed in the mind of the learner. The goal of this paper is to outline what has been called a radical constructivist model of knowledge and to outline how this model can help us understand chemical equation balancing.

The relationship between content specific knowledge and problem-solving ability is an important area that needs further clarification. Some work has already been done in describing the differences between experts and novices in their problem-solving techniques (Ravichandran, 2002 ; Simon & Simon, 2000) and in describing the knowledge possessed by problem solvers (Greeno, 1998). Much more descriptive work is necessary though if science educators want to understand what students can learn; what they understand of what they have learned, and how they use what they understand to solve problems. It is probably the case that students who fail to solve a given problem have used different knowledge than those who successfully arrived at a solution for that problem. But, what about students who successfully solve the same problem? Do they necessarily possess and use similar knowledge to arrive at the solution? The simple information contained is the fact that a student has obtained the correct (or incorrect) solution to a problem is too limited to be useful in answering this question. Additional information is required to completely determine the nature of the knowledge that a student possesses and in assessing the student's level of understanding of the problem.

Chemical equation balancing is widely taught in the chemistry curricula of Indian secondary and senior secondary schools (NCER T, 2002 a & b). This topic has been identified as a 'hard, spot' and poses great challenge in front of chemical educators. Much has been written on how to teach this content

(Oser, 1930; O'Bannion; 1950, Kolb 1978 ; Seetharamappa, 1997). While students and teachers consider chemical equation balancing to be one of the more difficult aspects of school chemistry (Ravichandran, 2002 ; Stewart, 1928; Ewing, 1931; Finley, Stewart, & ¥arroch, 1982), most students eventually learn how to successfully manipulate the coefficients and subscripts in order to successfully obtain the desired balanced results. However, there is some question as to how much these students understand about what the symbol manipulation represents within the context of the chemistry they have been taught (Ravichandran, 2002 ; Swartney, 1969; Glassman, 1967).

The present study also determines how high school chemistry students, who were successful in their ability to balance simple chemical equations, differed in their approach to balancing those equations and to obtain an assessment of what those students understood about the components of typical chemical equations and the rules used to balance them.

Method

A detailed description of how the students balanced chemical equations and a description of the knowledge the students possessed about equation balancing and the related chemistry concepts was required. Written achievement tests, if done well, can provide some information on the students' understanding of chemical equation balancing, but not enough (Stewart, 1980). Clinical interviews (Pines, Novak, Posner, & VanKirk, 1978) have been successfully employed by some mathematics (Mechinskaya, 1969; Kantowski, 1977) and science (Rowell, 1978; Stewart, 1982) educators in order to obtain more extensive information on what students know about specific science content or how they perform problem-solving operations.

An interview of a student, in order to find out the processes involved in obtaining a problem solution, can be very difficult if the problem to be solved is not novel to the student. Students can often obtain solutions to many well practiced problems even before they attempt to verbalise how they are solving the problem. Rather than have the students in this study balance equations in front of the interviewer while attempting to talk aloud, students were asked to tell the interviewer how to balance the equation that was written on a display board between them. The interviewer did all of the writing, but only at the command of the student. This slowed the problem-solving process down enough so that it was clear how each student was approaching the solution to the unbalanced equation presented to them.

Five hundred secondary school chemistry students from sixteen different schools of the western region of the country, namely the states of Goa, Maharashtra, Gujarat and Madhya Pradesh and Chhattisgarh (Goa, MH, GJ, MP and CH) were administered a 'test' (Annexure-I) and all the high achievers (>70% marks) in the test were interviewed on their ability to balance

chemical equations, the knowledge they employed while balancing the equations and their ability to represent the balanced equations with diagrams. The equations were of the type employed when students are exposed to chemical equation balancing in high school. It was desirable to use students who were already confident in their ability to balance chemical equations, since the objective of the research was to determine what the students knew beyond their ability to obtain correct answers. These students were also found to be better performing in the classrooms. Instruction on balancing chemical equations occurred in the secondary level and also at latter stages in all schools. The content dealt within the interviews was cogent to the teachers' instruction, and a fundamental component of the chemical knowledge expected to be learned by students at the high school level.

Interviews were recorded and lasted approximately 15 minutes. Each student was asked to read an equation aloud and then tell the interviewer how to proceed in balancing the equations (Annexure-I). After each equation was balanced, the interviewer attempted to determine the extent of the student's knowledge of the various components of the equation and the balancing process. This was done through questioning and having the student react to interviewer generated equation balancing results and diagrams. The interviewer used only the chemistry words introduced by the student during the interview and direct knowledge questions were avoided where possible. If a student did not use a relevant word or idea during the interview, despite being given the opportunity to do so it was introduced by the interviewer at the end of the interview. Students were also asked to explain their meaning for any word they used if it was not clear from the context of the interview.

The students' knowledge of chemical symbols, coefficients, and subscripts was especially sought, as well as knowledge of the two rules for balancing equations. The first rule is typically stated as there must be the same number of each symbol or element on both sides of the equation. This rule is derived from the empirical Law of Conservation of Matter that governs all chemical reactions. The second rule simply states that subscripts are not changed while balancing equations. The more meaningful expression of this rule can be found in the empirical Law of Definite Proportions for reacting chemicals.

Diagrams can be very useful in obtaining information about what a student knows. In equation balancing, diagrams are used more frequently in instruction than in testing. Therefore requesting a student to represent an equation in a diagram would provide alternative information about knowledge possessed. Their diagrams were meant to be simple representations of the equations and how the chemicals combined and recombined as indicated by the equation. The diagrams usually consisted of circles to indicate elemental particles, lines to indicate interaction or

linking between particles, and arrows to show the direction of the reaction. If what the student was representing was not clear, a request was made to label the diagram.

Results and Discussion

The performance of students in the administered test is given in Table 1. The student responses were grouped into three categories namely: A, B and C representing correct, partially correct and wrong responses, respectively. Best response for Q4 and Q10 and average performance on Q5 and Q7 clearly indicate that students although could do the job of balancing chemical equation, but do so without any proper understanding of the underlying concepts. This is substantiated by the poor response shown on Q2 and on other questions. In general about 25% of student population understood the chemical significance of equation balancing, another 25% did it correctly without understanding and the remaining 50% failed totally in doing so. The results observed are a real warning to teacher community and significant efforts in this direction is very much needed to make chemistry learning more meaningful and joyful. Further, analysis of the results (Table 2) indicated that there is no significant difference between the performances of boys and that of girls. However, the students of Central Board of Secondary Education (CBSE) performed significantly better than the students following the State curriculum.

Table 1: Students performance in the given test

Q.No.	Percentage of		
	A	B	C
1	21	28	51
2	18	21	61
3	9	36	55
4	31	16	53
5	25	19	56
6	18	33	49
7	24	20	56
8	0	22	78
9	0	12	88
10	28	24	48
11	6	60	34

A-Correct; B-Partially correct; C- wrong/ no response

Students found successful in balancing chemical equation were further tested for their real understanding and knowledge possessed the chemical concepts underlying of balancing chemical equation. All the students who were selected for the interview were able to successfully balance the equations presented to them. This result was expected as a consequence of the biased method used to select the sample. However, there were differences in what the students in this sample understood about the problems they solved, especially with the relationships between the mathematical aspects of those problems and the empirical and theoretical chemistry those problems were meant to represent.

The transcripts of the interviews were carefully analysed to determine how the students proceeded in solving these basic problems. There was little or no

variance between the students as each followed a procedure that consisted of two generalised, dependent subprocesses in arriving at a solution. This procedure is best represented using a linear algorithm (Fig. 1). The algorithm is specific to the chemical equation balancing problems used in the interviews. The first subprocess consists of an initial checking and manipulation of coefficients. This subprocess is performed only if necessary. It comprises the top half of the procedural algorithm. The lower half of the procedure consists of a rechecking subprocess to correct any imbalances that might have occurred during first half manipulations. The two subprocesses are repeated in turn until the equation is balanced. It should be noted that while most of the students used the same algorithm, few of the students who also had other problems with their understanding of chemical equation balancing, could not balance the decomposition reactions presented to them without an initial rewriting as synthesis reactions, doing the balancing, and then reversing the equation to report the results.

The largest differences between students occurred in their responses to queries dealing with their knowledge of the components of the equations and in their diagrams used to represent the balanced equations. The differences in knowledge were consistent with the contrast found in the students' diagrammatic representation of the balanced equations. Many (70%) of the students managed to make diagrams of the equations. Few (30%) students indicated that they could not or did not do so. The diagrams that were made could be divided into two distinct groups based upon how the elementary particles in the diagrams were organised. The diagrams of the first group could be described as representing a valid chemical interpretation of the equations. The diagrams of the second group represented alternative interpretations of the equations. These alternative diagrams were most consistent with a simple mathematical interpretation of

Table 2: Comparison of the performance among gender and Board of School Education

Category	per cent*	mean	Standard Deviation (SD)	t
Boys Girls	47 56	1.4 1.2	1.37 1.16	0.9**
CBSE State	81 33	3.2 1.0	1.88 0.51	8.1***

* Percentage of students correctly balancing the equation
** Not significant
*** Significant at 0.05 and 0.01 levels

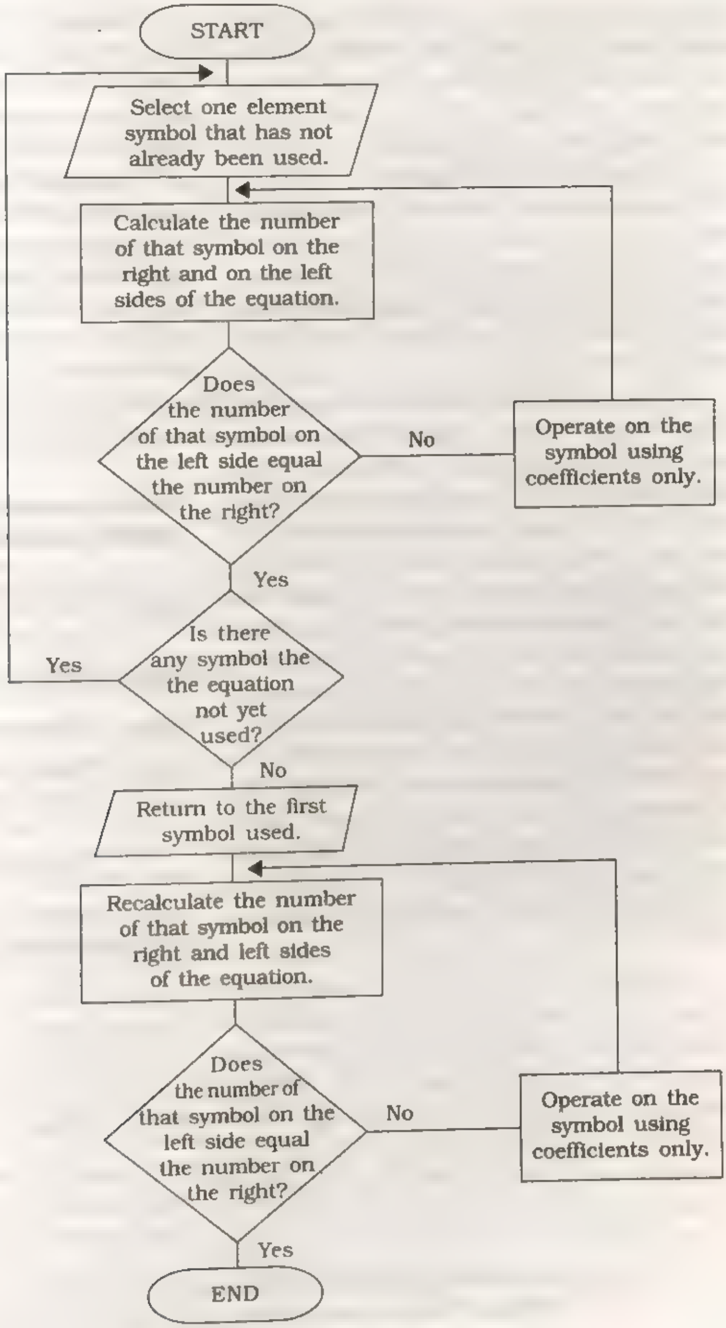

Fig. 1: Procedural representation of the process used by students to balance each of the interview equations.

the numbers and symbols in the equations. It is useful to contrast these two groups of students and describe the common features of the students' knowledge within each group.

Group One. The diagrams of 40% of the students were reasonably consistent with the notation of the balanced equation. For instance, if the equation called for three hydrogen molecules ($3H_2$) the diagram contained three sets of two linked circles (Fig. 2).

These students also shared similar knowledge about coefficients and subscripts. Coefficients were described as numbers that represented how many total units of each chemical symbol or formula was being represented. A common verbalisation used to describe the coefficient was to say that $2H_2O$ was the same as writing $H_2O + H_2O$. Subscripts were described by these students as representing the quantity of individual chemical symbols present in the formulas. This was usually expressed in terms of atoms (i.e., H_2 means two atoms of hydrogen) with the diatomic molecule case being the easiest to describe and to represent in a diagram (Table 3).

Multiples of polyatomic molecules gave few of the students some trouble. The trouble resulted from an uncertainty on the students' part concerning the physical relationships between the particles and the molecules when trying to represent them on paper. Their results were closer to being "H_4O_2" than to the "$2H_2O$" that they tried to represent. In both cases the students seemed to be wrestling with the problem of how to recombine the original molecular packets into new packets without breaking the old units.

Table 3: Portion of interview in which student expressed a good concept of subscript

Teacher:	Do you know what this little two here might be called?
Student:	Subscript?
Teacher:	Subscript ... what does it tell you?
Student:	Umm... that tells you the molecular form of the substance... whatever ... like you have two atoms forming one molecule of hydrogen.

Individuals in the first group also had similar knowledge with respect to the

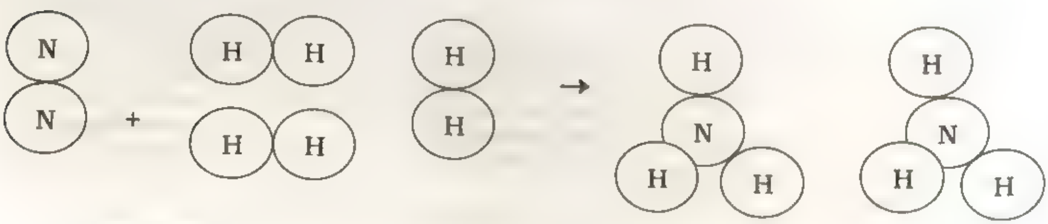

Fig. 2: Student representation of the chemical equation $N_2 + 3H_2 \rightarrow 2NH_3$ consistent with the coefficients and subscripts in the equation.

chemical reaction symbol (→). While they stated that this symbol had the same connotation as a mathematical equal sign (=) for the purpose of satisfying the Law of Conservation of Matter, they added that it was more than "Just" an equal sign. The additional meaning was stated in terms of it also meaning not equal since the chemical products formed were different from the chemical reactants (Table 4).

Table 4: Portion of interview in which student expressed a good concept of the reaction symbol (→)

Teacher:	What does this symbol represent?
Student:	Umm... a chemical change happening.
Teacher:	A chemical change happening?
Student:	Yeh!
Teacher:	Does it mean anything to you when you balance your equation?
Student:	Yeh ... that's like the dividing poTea, cause the number of ... urm ... atoms on the left has to equal the number of atoms on the right.
Teacher:	Would you feel free to call that an equal sign?
Student:	Umm ... not, not in a way I guess, cause you've got to have the number of atoms equal on both sides, but you're changing the ... the chemical ... uh ... properties, so the two things on each side aren't going to be the same.

Knowledge of the Law of Conservation of Matter was uniform in this group. All of these students worked from the assumption that symbols, elements, or particles were conserved in the equation balancing process. Mass, as an empirical quantity, was not referenced by students in this group when questioned as to why a given chemical equation was or was not balanced.

All the students in this group quickly recognised violations of the Law of Definite Proportions when they observed the interviewer incorrectly balance equations. They stated this law in terms of the rule for not changing subscripts, and would not allow any variance from this rule. Yet when questioned for their reason for the answers were very brief and not elaborated upon. One of the typical responses was that to change the subscripts meant that you no longer had the same substance anymore. The best response, given by the only student, was that changing subscripts meant changing the combining ratios of the elements and thereby changing the material represented.

In general, the knowledge demonstrated by the students in this group was not too different from that knowledge present in good instruction and in the chemistry textbooks.

Group Two. The remaining 60% students all made diagrams that were consistent with the total number of particles being manipulated but not consistent with the information supplied by the individual coefficients and subscripts. These students would typically represent three hydrogen molecules ($3H_2$) as six linked circles (Fig. 3).

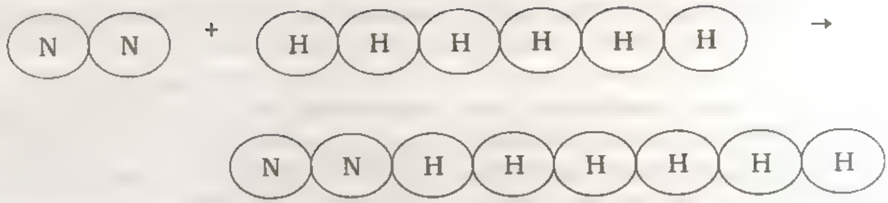

Fig. 3: Student representation of the chemical equation $N_2 + 3H_2 \rightarrow 2NH_3$ consistent only with the total number of particles in the equation.

This was reflected in their knowledge concerning the equation components. Their chemical knowledge of coefficients and subscripts was almost nonexistent Coefficients and subscripts were described as numbers distinguished primarily by their location in the equation. Both were said to give the same information, the number of symbols present (Table 5). The coefficient's function was to multiply the subscript and thereby balance the equation.

Table 5: Portion of interview in which student has difficulty expressing concepts of subscript and coefficient

Teacher:	... this little two here and this little four there. Is there a name for those things?
Student:	Subscripts?
Teacher:	Subscripts, that's a good enough name. What do they do? What Use do they have?
Student:	They tell... (let me think now)... they refer to the number of electrons in the outer shell... (I'm not sure about that) ... I just know their function, but not what they are...
Teacher:	Well, what's their function then, what do they do? When you are balancing this equation what does it do?
Student:	... (pause)... well, they're used to balance out the subscripts... or ... the ... the balance numbers that are up here ... in order to do that you have to put them down here and if there's already a number down here then you have to put the parenthesis around it, and ... put it out there... (I'm not sure).
Teacher:	What about this big number here? This two.. does that have a name?
Student:	... I know there's a name, but I can't think of it right now.
Teacher:	How about coefficient? What does it do?
Student:	It helps balance the equation, by .. having this number here and multiplying it by the subscript ... or vice versa ... you can get an equal number of the element on both sides.

In the same way this group of students described the chemical reaction symbol as simply a mathematical equal sign. It meant equal because there were supposed to be the same numbers of everything on both sides of the equation.

Knowledge of the Law of Conservation of Matter did not differ significantly from the knowledge possessed by the first group, although these students seemed to be more prone

to conserve symbols rather than mass or elementary particles. This was usually noted by the students stating the number of sodiums; irons, K's, Mg's, etc. were supposed to be equal rather than stating the number of iron atoms or the mass of the iron. These students were reluctant to use terms like atom or mole7cule even if the interviewer introduced the terms at the end of the interview.

Knowledge of the Law of Definite Proportions expressed by the members of this group was generally weaker than that expressed by the first group. When these students observed the interviewer incorrectly balancing equations by changing subscripts, they were uncertain as whether or not this could be done. Few said it was fine since you obtained the same information, others said it might be O.K. (Table 6). None of these students had a reason for why you could not change subscripts except to say that the teacher said so.

Table 6: Portion of interview in which student witnessed the interviewer balancing an equation by changing the subscript

Teacher:	Couldr I have done that?
Student:	No, you can't change the form of it in the beginning.
Teacher:	I can't change the form of it?
Student:	Well ... I don't know how to explain this.. um ... you can only change the coefficients, you can't change the... the state...
Teacher:	You only change the coefficient. but you can't change the ...
Student:	You can't. you can't change the state of what you started out with.
Teacher:	So if this is this... 2(HI) .. I can't change it to H_2I_2?
Student:	No.
Teacher:	This isn't the same thing... is that what you are saying?
Student:	I don't think it is.

In addition, the students who did not make diagrams of the equations they balanced could also be assigned to this group since their knowledge of the components of the equations differed little with respect to this knowledge compared to other members of the group who did attempt to make diagrams. These students were willing to violate the subscript rule.

In general, the knowledge of the relevant concepts and propositions exhibited by the students in the second group was less in substance and much more fragmented than the knowledge held by the students in the first group. The second group of students did possess the minimal knowledge necessary to successfully manipulate the symbols but were not able to demonstrate that they held additional knowledge about the symbols. The missing knowledge was the type that would provide depth to the concepts with respect to the role of the symbols within the discipline of chemistry. If any of this additional knowledge was present in these students, it tended to be fragmented and/or inconsistent. For instance, subscripts were said by few of the students to represent the number of atoms, but the related knowledge that subscripts also represented combining ratios of elements, or that coefficients represented molecular units did not seem to be present in the student's knowledge.

Question Nos. 8 and 9 consisted of complex questions and to answer these the students need to have sound basic chemistry knowledge on chemical equations and reactions. Question 10 consisted of questions with some formulae errors. The student need to spot the errors, correct them and then need to balance it. Question 11 tests students ability on chemical representations and their translations. Q 8 and Q 9 were not correctly answered by any student, but were at least attempted by few students. This reflects on their mathematical way of equation balancing and not by chemical concepts underlying them. In Q 10, about 28% of the students identified, corrected the errors and balanced the equation. About 24% identified but wrongly corrected and 48% did not attempt at all. The results revealed that the poor performance is due to their poor knowledge of chemical symbols, valencies, determination of chemical formula from valency, identification of elements from their symbols, writing molecular formula and on subscripts. In the case of Q 11, about 6% of the student population correctly answered it. But many of the students however answered it partially.

Sixty per cent of chemistry students interviewed clearly demonstrated that although they could balance simple chemical equations to achieve a correct result, they had little understanding of the chemical implications of the equations. This lack of understanding was evidenced by the students' inability to adequately diagram the equations and their corresponding poor conception of the function of coefficients and subscripts as well as their poor understanding of the empirical laws governing the use of these concepts in equation balancing. Both shortcomings seem to be related since students failed to incorporate knowledge implicit in the concepts and empirical laws in their diagrams of the equations. Those students who were able to construct adequate diagrams of the equations also gave evidence that they had a greater understanding of the concepts and a somewhat better understanding of the laws involved in equation balancing.

The analysis of the interviews of the students in this study also indicated that students who were good at solving these simple problems used similar procedures in obtaining their answers yet differed markedly in the knowledge they possessed and applied to the problems. This difference in the quality of the knowledge held seems to indicate that the students could solve the problems with at least two distinct levels of understanding. The higher level of understanding incorporated the usefulness of the abstract symbols in chemical explanation, while the lower level could be described as an efficient, mathematical manipulation of symbols.

While this lack of chemical understanding in the lower levels did not hinder the students in balancing the simple equations used in the interview, it is possible that it would become an important factor in the solution of more difficult equations encountered at later stages of the chemistry course. These students may be less able to recognise errors they had made than those students who possessed a better

understanding of this content. An example would be the balancing of redox equations where the simple manipulation of symbols is not a guarantee of a solution and a deeper knowledge of the theory behind the equations can provide clues to the solution.

It is also important to note that all of the students in this study were evaluated by their respective teachers to be high achievers with respect to the chemistry knowledge. Despite this fact, the majority of the students were not able to demonstrate that they knew anything more about chemical equation balancing than the mechanical manipulation of symbols. Unfortunately, the mechanical manipulation of symbols is enough to satisfactorily pass the evaluation instruments prepared by most teachers. Measurement instruments need to be designed to not only measure ability to balance chemical equations, but also the knowledge attached to the balancing process, and the relationships between the two.

In order to find out the students thinking pattern and cognitive structure (Taagepera & Noori, 2000), Knowledge Space Theory (KST) (Taagepera & Potter, 1997)was applied on students responses in the test and interview. A computer program was written in C++ to identify the frequency of different pattern of student responses. The pattern responses and the frequency were fed into another Basic program meant for KST analysis (Potter, 2002). A specific critical learning pathway analysis is given in Fig. 4. There were two main pathways as shown in Fig. 4. This clearly indicate that students learn chemical equation balancing mainly as a mathematical calculation without understanding the chemical concepts underlying that. The misconceptions too became very obvious in the present study. Many students were unable to reason why they need to balance chemical equations and the significance of coefficients and subscripts of the symbols. It also indicates that we need to spend a lot more time on making connections than we generally do, regardless of the organising principles that we use.

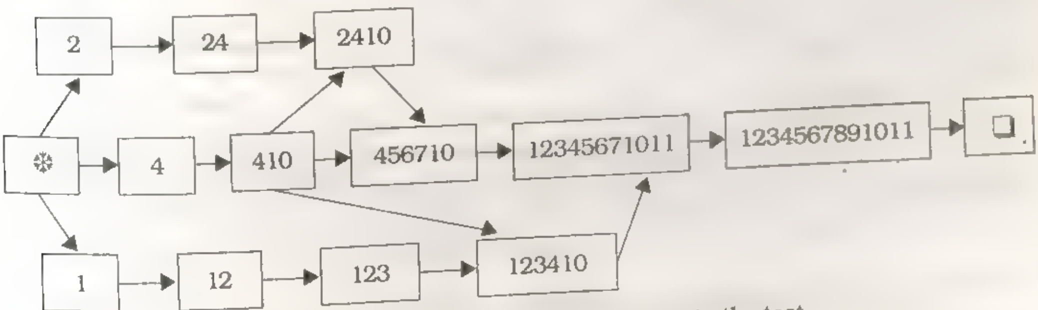

Fig. 4: Knowledge structure for students in the test.

❆-initial state; ❑final state; ▭ knowledge state; ➤-critical learning pathway for most students.

123 - represents students who had answered Q1, 2, 3 correctly.

Concept mapping is an effective method successfully used in science teaching-learning processes (Ravichandran, 2002 ; Mary & Joseph, 1990). A concept map on chemical equation balancing was developed with the help of subject experts and is given in Fig. 5. The overlap of KST data obtained above on this concept map reveal several significant missing links in students thinking pattern. These links are shown in bold in Fig. 5. This again supports the above finding that students do not understand the chemical concepts underlying chemical equation balancing. These missing links has to be appropriately dealt while teaching in class room so that students understand the concepts and their connections more meaningfully.

Knowledge is constructed in the minds of learner; and it 'fits' rather than 'matches' reality. It is the difference between the concept of 'fit' and 'match' that shows how radically constructivism differs from the traditional view of

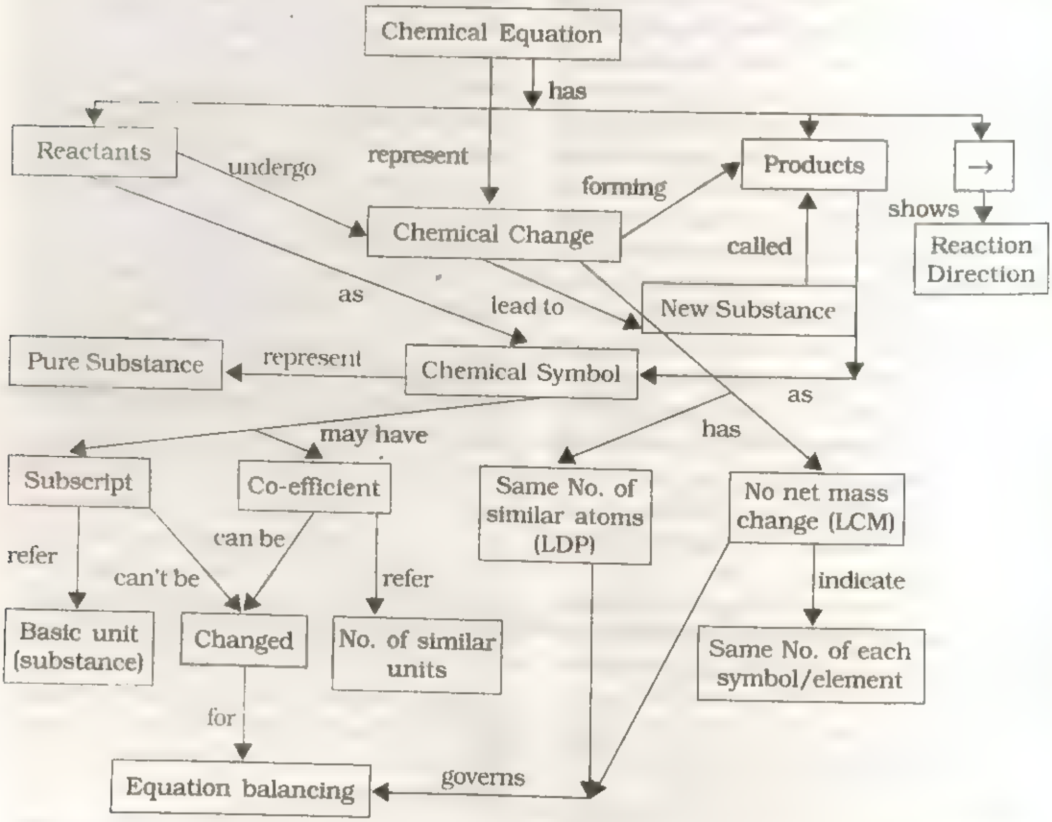

Fig. 5: Conce[illegible]p on chemical equation balancing. (LCM—Law of Conservation of Matter; [illegible] of Definite Proportion, [illegible] missing links)

knowledge. The constructivist model also explains why student bring misconceptions to chemistry classes and why these misconceptions are so remarkably resistant to instruction. The most important single factor influencing learning is what the learner already knows. To learn meaningfully, individuals must choose to relate new knowledge to relevant concepts and propositions they already know. In rote learning... new knowledge may be acquired simply by verbatim memorisation and arbitrarily incorporated into a person's knowledge structure without interacting with what is already there.

The constructivist model of knowledge has important implications for instructions. Social knowledge such as chemical symbols for the elements can be taught by direct instruction. It can even be argued that this is the only way that children can learn social conventions. But physical and logicomathematical knowledge cannot be transferred intact from the mind of the teacher to the mind of the learner. The constructivist model therefore requires a subtle shift in perspective for the individual who stands in front of the classroom. A shift from someone who 'teaches' to someone who tries to facilitate learning; a shift from teaching by imposition to teaching by negotiation.

Finally, if the findings of this study represent the results of typical instruction in high school chemistry classrooms, then there is a potential implication for the curriculum. First, the chemistry curriculum will need to be reorganised in order to place more emphasis in instruction on the nature and use of subscripts in chemical formulas and on the nature and use of coefficients in chemical equation balancing. Second, emphasis also needs to be placed on the relationship between the mechanics of balancing equations and the conceptual understanding of the chemistry implied by those equations. The meaningful learning of chemical equation balancing is a more appropriate goal for instruction than the correct solution of unbalanced equations.

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Annexure-I

Regional Institurte of Education (NCERT), Bhopal

Test for Identifying student's understanding of Chemical Equation Balancing

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1. Why do you want to balance chemical equations?
2. What strategy do. you follow to balance a chemical equation?
3. What additional information could be obtained from a balanced chemical equation?
4. Balance the following chemical equations.

   (a) $N_2 + H_2 \rightarrow NH_3$

   (b) $F_2 + Xe \rightarrow XeF_4$

   (c) $HI \rightarrow H_2 + I_2$

   (d) $I_2 + Br_2 \rightarrow IBr$

   (e) $Fe + O_2 \rightarrow Fe_2 0_3$

5. What does the small numbers represent in the above equations? How do you call it?

   Can you change it for balancing the equation? Why?

6. What does the symbol '$\rightarrow$' represent in the above equations? Does it mean equal sign for balancing equation?
7. What does the big numbers represent in the above equations? How do you call it?

   Can you change it for balancing the equation? Why?

8. Balance the following equation using different sets of coefficients. (i.e. in all possible ways)

   $CO + C0_2 + H_2 \rightarrow CH_4 + H_2O$

9. Attempt balancing the following equation.

   $(NH_4)_2SO_4 \rightarrow NH_4OH + SO_2$

   Explain your answer.

10. Correct the errors in the following equations and then balance them.

    (a) $H_2 + I \rightarrow HI$

    (b) $Cu_2\ SO_4 + Fe \rightarrow Fe(SO_4)_2 + Cu$

(c) $BaNO_3 + H_2\ SO_4 \rightarrow BaSO_4 + HNO_3$

(d) $Al(OH)_3 + K \rightarrow K(OH)_3 + Al$

(e) $NaO + H_2O \rightarrow Na(OH)_2$

11. Which of the following must be equal on both sides of a balanced equation?

(a) number of atoms

(b) number of molecules

(c) number of each type of atom

(d) mass

(e) charge

(f) any other answer (specify).

Chemistry of Azides and Explosives

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Explosives and azides are materials that can expand violently by passing from a solid to a gaseous state in a very short time. These substances store large amount of energy that can be suddenly released when subjected to friction, heat, shock or impact making the substance to expand with great velocity (Coursen, 1997).

During this, explosive generate loud noise leading sometimes to destructive actions on subjects in the surrounding. The earliest known explosive to man was a mixture of sulphur, charcoal and potassium nitrate. This type of explosive is not common nowadays because it is expensive and takes longer time to manufacture. Modern day explosives are in plastic form and easy to manufacture.

Explosives are exclusively used on ammunition, in mining, quarrying, demolition work, excavation of oil and gas as well as in prospective for petroleum. Explosives are mostly nitrate compounds e.g. ammonium nitrate ($NH_4 NO_3$) and can explode by itself.

Nitrate compounds are ingredients of explosives e.g. cellulose nitrate, glyceryl or nitro glyceryl are some nitrogen containing explosives. Tertryl ammonium picrate, cyclonite or hexagen (RDX) are widely used as explosives. Some fumigants (gaseous disinfectants or insecticides) can act as explosive on exposure to air e.g. hydrogen cyanide and carbon disulphide (Wilbur, 1997). Many other explosives include nitroglycerine (NG), trinitrotoluene (TNT), triniss-trophenylmethylnitramine, (TETRYL) cyclotrimethylenetrinitrate, pentaery-thritotetranitrate (PETN) and Hexanitrostilbene (HNS). etc.

Brief History of Explosives

The earliest explosive was a black powder discovered by the Chinese centuries ago, which was a mixture of sulphur, charcoal, and potassium nitrate and was used in propelling missiles shortly after the 1300's. Later nitroglycerin and nitro cellulose were discovered shortly before 1850. Dynamites were invented and atomic explosive were first detonated in 1945. Superior products such as smokeless powder, which was first manufactured in 1897, have been developed over the years (Shreve, 1967). Use of chlorates which chlorate salts of chloric acid and perchlorates (salts of perchloric acids) as base for explosives dates back to as far as 1788.

Classification of Explosives

The different classes are mechanical, chemical, nuclear, military and industrial explosives.

Mechanical Explosives: These are devices, which detonate depending on physical reaction such as overloading a container with compressed air. Such devices have some applications in mining where the release of gas from

chemical explosive may be undesirable, but otherwise has a very limited application.

Nuclear Explosive: Explosives which have sustained nuclear reaction that can take place with almost instant rapidity releasing large amount of energy very useful in petroleum prospecting.

Chemical Explosives: These explosives depend on chemical reactions within them. There are deflagrating low explosive, which explode with very low velocity at slow rate while detonators explode suddenly with high velocity. This later class is very sensitive to heat; friction or impact e.g. lead azide $Pb(N_3)$, nitrogen cellulose (NG) trinitrophenyl-methynitroamine (TETR YL).

In most explosive industries 914 $msec^{-1}$ is arbitrarily used as the velocity dividing line between deflagration (explosion with low velocity) and a detonation (violent or sudden explosion). Deflagrating (low) explosives are those that often decompose at a rate much below the sonic velocity of material, without any excess of atmospheric oxygen being required. It is being propagated by the liberated heat of reaction and the direction of the reaction products is opposite that of the decomposition propagation (unlike detonators). Examples include rocket propellants gunpowder, nitroglycerin (Nwadinigwe, 1995).

Industrial Explosives: These are explosives, which have large critical diameters, lower densities, velocities and explosion pressure with more complex composition (Onwuchekwa, 2000). They contain ingredients such as sensitizers, fuels, and oxidisers in intimate combination. They are packaged in bags or cartridges of polymer films where they are blown or pumped into the holes in the mine through hoses. Aqueous explosives contain an aqueous phase saturated with inorganic nitrate or perchlorates with fuel (e.g. ground coal) and a sensitiser such as trinitrotoluene (INT) in hollow gland spheres. They are very useful in mining (Onwuchekwa, 2000).

Military Explosives: These are explosives, which have excellent shattering power than other explosives used for commercial or industrial purposes. Apart from theses, they must possess power to withstand long periods of adverse storage without deterioration and able to drop aerial time bombs without premature explosion. Most of them are composed of chemical compounds that incorporate both oxidisers and fuel components in the same molecule. Typical examples of military explosives are trinitrotoluene (TNT), trinotrophenylmethylnitramine (TETRYL), cyclotrimethylnitramine (RDX), Hexanitrostilbene (HNS) etc. These explosives can be used to transfer denotation from one point to another in military devices and also in commercial blasting.

Properties of Explosives

Most explosives contain chemical groups that have the characteristics of oxidisers and fuels, which serve as the principal reacting ingredients. Some molecular explosives e.g. TNT, TETRYL are energetic within themselves and do not require

additional component in order to undergo powerful detonation. Some sensitisers are added to increase the sensitivity of explosives. Such sensitisers include nitroglycerin, aluminium mono-methylamine nitrate, mono-methylamine nitrate, microballons and aerating agents. Some oxidising chemical groups in explosives that serve to oxidise - CH_2 - CH_2 - group containing portions of explosives are NO, NO_2, ClO_3 - Nf etc. Heat are generated when explosive detonate in a measure of the energy released. For example some chemical reaction involved to release energy is shown below:

$3NH_4NO_3 + (CH_2)_n$ ③
$7H_2O + CO_2 + 3N_2 + 0.93Kcal/g$ ...(i)

$5NH_4NO_3 + (CH_2)_n$ ③ $11H_2O + CO_2 + HN_2 + 0.6Kcal/g$ ...(ii)

Equation (i) represent a fuel sufficient situation while equation (ii) represent fuel deficient situation in which no poisonous gasses are produced in equation (i) but in the second equation some of the nitrogen from ammonium nitrate combine with excess oxygen to form nitrogen (NO) which reacts with oxygen to give the toxic nitrogen dioxide (NO_2). The carbon monoxide (CO) in equation (i) a fuel rich situation is less than nitrogen oxide (NO) and nitrogen dioxide (NO_2) in the fuel deficient situation in equation (ii). Hence fuel rich situation is favoured in explosives.

Application of Explosives

Explosives are utilised mostly in military, industrial and commercial applications. ***Military Applications***: High-energy explosives are used for the firing of shell, bombs, warheads, mines, torpedoes and grenades. In marine application under water are demolished by placing charges on these obstacles, which break up during explosion. A powerful slurry explosive known as DBA - 22M was used for clearing helicopter-landing zones in jungles of Cambodia during American operation in Cambodia in 1970 (Cook, 1958).

Tear gas – a riot control agent contain explosive such as chlorobenzylidienemalonitrile $ClC_6H_5CHI(CCH)_2$ and chloroacetophemone (C_8H_7CLO). Tear gas which explo when thrown cause physiological effects on human such as extreme burning of the eyes accompanied with a flow of tears, coughing, running nose, dizziness etc.

Industrial Applications: Industrially, explosives are used in mining of mineral ores, coal and rock containing minerals. Also used in generating vibrations in seismic prospecting for crude oil and gas, bonding sheets of dissimilar metals to each other. Aircraft parts may be constructed with explosive rivets, which help to save time and effort. New versatile and economical methods of fabrication technique of machine parts are done with the use of powerful explosives (Shreve, 1967).

Explosive bonding or cladding can also be used to bind metallurgically incompatible metals such as aluminium and steel. Also ships wreckage and debris can be cleared from harbour and pieces of ship can be removed out of the way by using explosives (Milwee, 1997).

In conclusion, explosives though it can be harmful to man depending

on usage can be very useful to man. Its use in military and also in engineering works has enabled man to perform many tasks, which would have been physically or economically impossible. Their use too in the field of military, industry, and commerce are immense.

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Concept of Force: An Investigation of Teachers' Understanding

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CONCEPT of **Force** is very fundamental in basic physics. Its effects are distinctly perceptible in every branch of physics; mechanics, dynamics, electromagnetism, gravitation, nuclear and particle physics or any other branch of science. Force has a basic role of **Cause** in almost every scientific phenomenon. One begins experiencing force from an early age in life. A student of science begins formal learning about force from elementary level yet conceptual clarity eludes many for a quite long time. Teachers are also not free from misconcepts and alternative frames about force. Misconcepts of teachers can easily pass on to students. We have examined a group of 21 teachers using Force Concept Inventory (FCI) of Hestenes et al. (1992). It is a multiple choice test which has been used as an assessment tool at every level of introductory physics from high school to university. Hake (1998) has highlighted its use fullness in evaluating students' understanding even before any formal teaching begins. It is an effective diagnostic tool to examine conceptual understanding of basic concepts of force in a way that is understandable to beginners as well as the learned ones. In other words, by using FCI as an analytical tool the teacher moves beyond the position of having a general awareness that students are **having difficulties** with conceptual dimensions of force to being able to interpret the students' thinking more objectively. Teacher is thus in a better position to plan and implement the next stage of teaching. It is found that FCI is not only a potent tool for improving students' learning but also equal important for improving the teachers' understanding and approaches in the subject. It has been reported that an FCI score of 60% is regarded as being the **entry threshold** to concept of force. Below that students' grasp of concepts of force is insufficient for effective problems solving. Later Halloun and Hestenes (1995) reported that an FCI score of 85% is regarded as being the **mastery threshold** of concept of force. As we know that teachers are very important component of physics education which have deep influence on students' learning of the subject. Often the misconcepts of the teachers are passed on to the students (Sharma and Sharma, 2003 and references cited therein). Keeping above in view, it was decided to conduct a study of teachers' understanding of basic conceptual dimensions of force using FCI of Hestenes et al. (1992). The results of this study are presented and discussed in the following sections.

Plan of Study and Tool

Force concept inventory (Hestenes et al, 1992) a questionnaire consisting of total number of 29 questions related to the basic conceptual dimensions of force viz. kinematics, Newton's first law, Newton's second law, Newton's third law, superposition principle and kinds of forces (Appendix) having five multiple choice options (except question number 16) was administered on a group of 21 physics PGTs of senior secondary schools of repute. The teaching experience of the sample extended from 5 to 25 years with an average at about 12 years. The responses given by the teachers are analysed and efforts were made to identify the cause of incorrect responses.

Sample

The sample consisted of 21 representative teachers, teaching physics at senior secondary level in different schools of repute in the country; each teacher had at least Master degree in Physics. Most of the teachers had M.Sc.; B.Ed and some teachers had M.Ed. degree too. They had teaching experience in the range of 5 to 25 years. Out of 21 teachers 15 were male and 6 were female teachers. However, during analysis the sex of the teacher was ignored. When questionnaire was administered, no time limit respond to the questions was set. Teachers were given as much time as they required to answer to all the questions. However, it was noted that 95 minutes duration was sufficient to all the teachers to answer the questionnaire completely.

Table 1: Analysis of responses related with the different concepts of force

Concept	Question No.	Unresponded options	Correct options	Wrong options	% of wrong options
Acceleration mass/weight relationship	1	01	19	01	05
Newton's third law	2	–	18	03	15
Acceleration independent of mass/ weight	3	02	10	09	43
Motion under no force	4	–	19	02	10
Role of force of gravity	5	–	05	16	77
Vector addition of displacements	6	–	12	09	43
Vector addition of velocities	7	01	15	05	24

Newton's first law with no force	8	01	06	14	66
Force due to action - reaction	9	02	04	15	71
Newton's law with no force	10	—	14	07	33
Newton's third law	11	—	15	06	29
Balancing action-reaction forces	12	—	13	08	38
Newton's third law	13	—	08	13	62
Newton's third law	14	03	13	05	24
Impulsive action-reaction	15	—	07	14	67
Trajectory of a projectile	16	01	13	07	33
Gravitational force	17	01	02	18	85
Constant velocity – balancing upward and downward force of gravity	18	01	10	10	47
Superposition principle vector sum	19	09	18	03	14
Speed dx/dt – rate of change of position	20	02	08	11	52
Acceleration dv/dt – rate of change of speed/velocity	21	01	02	18	86
Motion under gravitational force	22	01	07	13	62
Trajectory under superposition of two velocities	23	—	18	03	14
Constant acceleration parabolic path	24	03	02	16	77
Constant acceleration	25	—	09	12	57

Newton's first law with no force	26	4	05	12	57
Newton's first law: Speed constant	27	2	14	5	24
Newton's first law with cancelling forces	28	2	7	12	57
Kinds of force-friction opposes motion	29	—	8	13	62

Analysis of the responses and results

Response to each question was analysed and discussed to understand the reasons of options favoured by the teachers. The following conclusions can be broadly drawn.

1. All the teachers responded to almost all the questions. However, 28 options were not responded out of total responses 609. In some cases there were very few correct responses e.g. question numbers 5, 7, 21 and 24 (Table 1).
2. The average correct response per teacher is only about 50%. There was only one question which was answered correctly by 90% of teachers (Table 1). Eight questions were responded correctly by 36% teachers.
3. The responses to question clearly point out a lack of understanding of the basic concepts of force and related kinematics. Some typical cases are discussed below.

In the response to question no.5 of force concept inventory given in Appendix, 10% teachers chose option (a), 10% (b), 52% (c) and 5% (e) instead of correct option (c). This option was given by 23% teachers. It seems that the teacher's understanding of the concept of role of force of gravity is not sound enough. Question no.8 related to concept of Newton's first law with no force was also not understood correctly. 19% have chosen option (b), 49% (c), 33% (d) and 10% (e). The correct option here was (a). However, in this question five per cent teachers have not responded to any option. In question number 9 concepts of force due to action reaction was examined. 5% teachers have chosen option (a), 57% (c), 10% (e) and 9% have not opted any. Here (d) is the correct option. In all 19% teachers responded to this option. Application of Newton's third law has been examined in question no. 13 for which 62% teachers have given wrong responses and remaining 38% have opted for the correct option (a). Out of 62% wrong responses, 10% responded to (b), 33% to (c) and 19% to (d) option. Question number 15 was related with the concept of impulsive action-reaction. In this question 24% teachers have opted (a) and 43% (b). The correct response here was (c) responded by 33% of the teachers. Question no. 17 was barely

understood by the teachers as 85% teachers have applied wrong approach in answering this question. The effect of gravitational force was to be examined to understand this question. In response to question number 21, 14% teachers have selected option (a), 43% (b), 24% (c) and 5% (e) instead of the correct option (d). However, 5% teachers have not responded any option. Here concept of acceleration i.e. rate of change of speed had to be applied. The concept of motion under gravitational force was examined in question no. 22. In response to this question, 5% teachers opted option (a), 9% (b), 43% (c) and 5% (e). The correct response was (d) which was given by 33% of the teachers. Five per cent teachers have not responded any of the options for this question. In regard to question number 24 of the FCI, where the concept of constant acceleration parabolic path was checked, 10% teachers selected option (a), 33% (b), 10% (c) and 24% (d). Remarkably 14% teachers have not responded to any option of this question. The correct response (e) was given by only 9% teachers. The concept of constant acceleration was investigated here in question number 25 for which 57% teachers have opted wrong options whereas 43% have opted the correct option. Question number 26 was dedicated to the concept of application of Newton's first law with no force. This question was responded by 24% teachers correctly whereas 57% teachers have opted wrong options as 5% (a), 24% (c), 3% (d) and 5% (e). Surprisingly 19% teachers have not opted any response. In this question concept of Newton's first law with concelling forces had to be examined. The concept of kinds of force-friction opposes motion was understood by 38% teachers correctly as they opted the correction option (c). Other options responded by 62% teachers include 9% (a), 43% (b) and 10% (d).

Discussion and Implications

The examination of the teacher's responses give the clear impression that a significant fraction of teachers carry misconceptions. This is despite of the fact that all the teachers are well qualified and having teaching experience of several years. The sample could well be taken to be a representative sample, it could therefore be concluded that similar conditions prevail elsewhere too. The existence of misconceptions among the teachers has serious implications and likely to be passed on to their students-Sharma & Sharma (2003). Steinber and Sabella (1997) have administered the FCI to the introductory calculus-based physics classes at the University of Maryland. They have reported that student understanding of the force concept is often incoherent, as only 54% answered the FCI correctly. There is thus a very strong case for frequent in-service refresher courses of reasonably long duration for the teachers. It is worth mentioning over here that the sample of teacher is small, therefore, the percentages depicted could only be an indicator of the trends. However, following points may be suggested to the teachers teaching in the classroom.

(i) Teachers may set the subject matter clearly and key features of conceptual dimensions must be identified before delivering to the students. It may also be ensured that students develop sufficient application skills and problem solving techniques through simple and exemplary questions/problems.

(ii) Teachers should move beyond the position of having a general awareness that students are having difficulties with parts of the Newtonian Physics to being able to interpret the student's thinking more analytically so that the teachers are in better position to plan and to implement the next stage of teaching.

(iii) Teachers may adopt interactive approach for effective transaction to enhance students' conceptual understanding.

(iv) Teachers should plan their lessons, activities, questions, etc. focusing on the understanding and application of the basic concepts related to the subject.

(v) A feedback from the students at the end of the lecture will be taken and then self-analysis of the lecture should be done.

(vi) Feedback should also be critically analysed by other fellow teachers.

(vii) Finally remedial measures should then be taken to rectify the misconcepts of the students.

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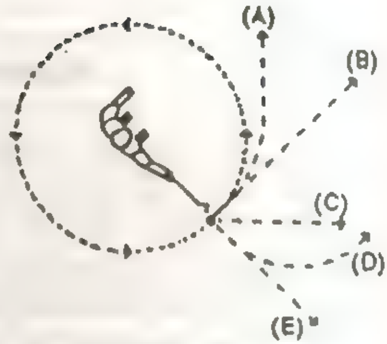
Appendix

Force Concept Inventory

1. Two metal balls are of the same size, but one weighs twice as much as the other. The balls are dropped from the top of a two store building at the same instant of time. The time taken by the balls to reach the ground below will be:
   (a) about half as long for the heavier ball.
   (b) about half as long for the lighter ball.
   (c) about the same time for both the balls.
   (d) considerably less for the heavier ball, but not necessarily half as long.
   (e) considerably less for the lighter ball, but not necessarily half as long.
2. Imagine a head-on collision between a large truck and a small compact car. During the collision,
   (a) the truck exorts a greater amount of force on the car than the car exerts on the truck.
   (b) the car exerts a greater amount of force on the truck than the truck exerts on the car.
   (c) neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
   (d) the truck exerts a force on the car but the car doesn't exert a force on the truck.
   (e) the truck exerts the same amount of force on the car as the car exerts on the truck.
3. Two steel balls, one of which weighs twice as much as the other, roll off from a horizontal table with the same speed. In this situation:
   (a) both balls impact the floor at approximately the same horizontal distance from the base of the table.
   (b) the heavier ball impacts the floor at about half the horizontal distance from the base of the table than does the lighter.
   (c) the lighter ball impacts the floor at about half the horizontal distance from the base of the table than does the heavier.
   (d) the heavier ball hits considerably closer to the base of the table than the lighter, but not necessarily half the horizontal distance.
   (e) the lighter ball hits considerably closer to the base of the table than the heavier, but not necessarily half the horizontal distance.

4. A heavy ball is attached to a string and swung in a circular path in a horizontal plane as illustrated in the diagram to the right. At the point indicated in the diagram, the string suddenly breaks off the ball. If these events were observed from directly above, indicate the path of the ball after the string breaks.



5. A boy throws a steel ball straight up. Disregarding any effects of air resistance, the force(s) acting on the ball until it returns to the ground is (are):

(a) its weight vertically downward along with a steadily decreasing upward force.

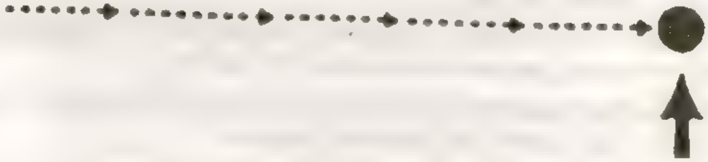
(b) a steadily decreasing upward force from the moment it leaves the hand until reaches its highest point beyond which there is a steadily increasing downward force of gravity as the object gets closer to the earth.

(c) a constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point, after which there is only the constant downward force of gravity.

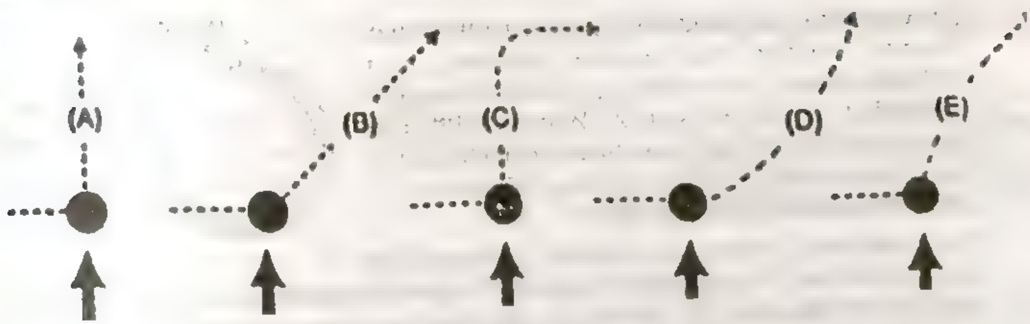
(d) a constant downward force of gravity only.

(e) none of the above. the ball falls back down to the earth simply because that is its natural action.

Use the statement and diagram below to answer the next four questions: The diagram depicts a hockey puck sliding with a constant velocity, from point 'a' to point 'b' along a frictionless horizontal surface. When the puck reaches point 'b', it receives an instantaneous horizontal "kick" in the direction of the heavy print arrow.

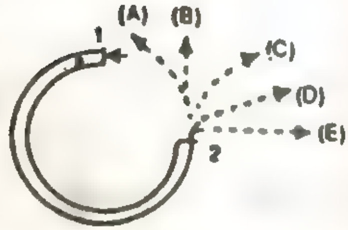


6. Along which of the paths below will the hockey puck move after receiving the "kick" ?



7. Does the speed of the puck just after it receives the "kick" is
   (a) equal to the speed "v_o" it had before it received the "kick"?
   (b) equal to the speed "v" it acquires from the "kick", and independent of the speed "v_o"?
   (c) equal to the arithmetic sum of speeds "v_o" and "v"?
   (d) smaller than either of speeds "v_o" of "v"?
   (e) greater than either of speeds "v_o" or "v", but smaller than the arithmetic sum of these two speeds?
8. Along the frictionless path you have chosen, how does the speed of the puck vary after receiving the "kick"?
   (a) No change.
   (b) Continuously increasing.
   (c) Continuously decreasing.
   (d) Increasing for a while, and decreasing thereafter.
   (e) Constant for a while and decreasing thereafter.
9. The main forces acting, after the "kick", on the puck along the path you have chosen are:
   (a) the downward force due to gravity and the effect of air pressure.
   (b) the downward force of gravity and the horizontal force of momentum in the direction of motion.
   (c) the downward force of gravity, the upward force exerted by the table, and a horizontal force acting on the puck in the direction of motion.
   (d) the downward force of gravity and an upward force exerted on the puck by the table.
   (e) gravity does not exert a force on the puck, it falls because of the intrinsic tendency of the object to fall to its natural place.

10. The accompanying diagram depicts a semicircular channel that has been securely attached, in a horizontal plane, to a table top. A ball enters the channel at "1" and exits at "2". Which of the path representations would most nearly correspond to the path of the ball as it exits the channel at "2" and rolls across the table top?



Two students, student "a" who has a mass of 95 kg and student "b" who has a mass of 77 kg sit in identical office chairs facing each other. Student "a" places his bare feet on student b's knees, as shown below. Student "a" then suddenly pushes outward with his feet, causing both chairs to move.

11. In this situation,

(a) neither student exerts a force on the other.

(b) student "a" exerts a force on "b", but "b" doesn't extert any force on "a".

(c) each student exerts a force on the other but "b" exerts the larger force.

(d) each student exerts a force on the other but "a" exerts the larger force.

(e) each student exerts the same amount of force on the other.

12. A book is at rest on a **table**. Which of the following force(s) is (are) acting on the book?

1. A downward force due to gravity.
2. The upward force by the table.
3. A net downward force due to air pressure.
4. A net upward force due to air pressure.

(a) 1 only

(b) 1 and 2

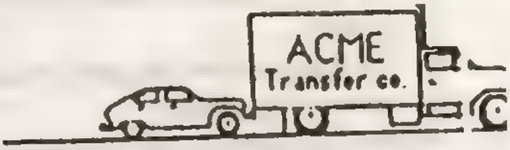
(c) 1,2, and 3

(d) 1,2, and 4

(e) none of these, since the book is at rest and there are no forces acting on it.

Refer to the following statement and diagram while answering the next two questions.

A large truck breaks down on the road and receives a push back into town by a small compact car.



13. While the car, still pushing the truck, is speeding up to get up to cruising speed:
    (a) the amount of force of the car pushing against the truck is equal to that of the truck pushing back against the car.
    (b) the amount of force of the car pushing against the truck is less than that of the truck pushing back against the car.
    (d) the amount of force of the car pushing against the truck is greater than that of the truck pushing against the car.
    (d) the car's engine is running so it applies a force as it pushes against the truck, but the truck's engine is not running, so it can't push back against the car, the truck is pushed forward simply because it is in the way of the car.
    (e) neither the car nor the truck exert any force on the other, the truck is pushed forward simply because it is in the way of the car.
14. After the person in the car, while pushing the truck, reaches the crusing speed at which he/she wishes to continue to travel at a constant speed:
    (a) the amount of force of the car pushing against the truck is equal to that of the truck pushing back against the car.
    (b) the amount of force of the car pushing against the truck is less than that of the truck pushing back against the car.
    (e) the amount of force of the car pushing against the truck is greater than that of the truck pushing against the car.
    (d) the car's engine is running so it applies a force as it pushes against the truck; but the truck's engine is not running, so it can't push back against the car, the truck is pushed forward simply because it is in the way of the car.
    (e) neither the car nor the truck exert any force on the other, the truck is pushed forward simply because it is in the way of the car.
15. When a rubber ball dropped from rest bounces off the floor, its direction of motion is reversed because:
    (a) energy of the ball is conserved.

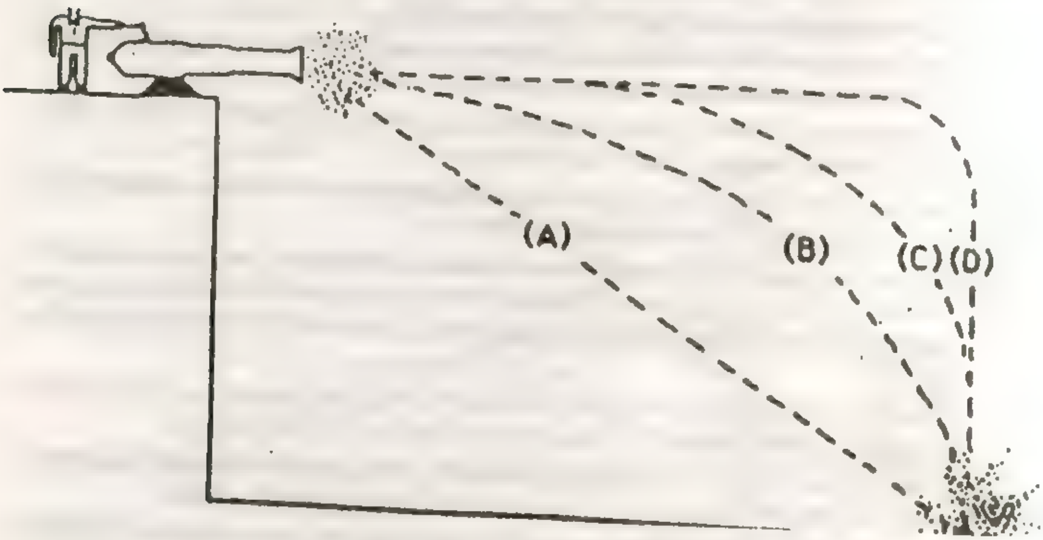
(b) momentum of the ball is conserved.

(e) the floor exerts a force on the ball that stops its fall and then drives it upward.

(d) the floor is in the way and the ball has to keep moving.

(e) none of the above.

16. Which of the paths in the diagram best represents the path of the cannon ball?



17. A stone falling from the roof of a single storey building to the surface of the earth:

(a) reaches its maximum speed quite soon after release and then falls at a constant speed thereafter.

(b) speeds up as it fails, primarily because the closer the stone gets to the earth, the stronger the gravitational attraction.

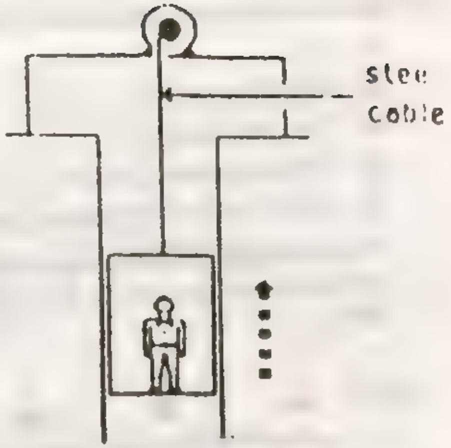
(c) speeds up because of the constant gravitational force acting on it.

(d) falls because of the intrinsic tendency of all objects to fall toward the earth.

(e) falls because of a combination of the force of gravity and the air pressure pushing it downward.

When responding to the following question, assume that any frictional forces due to air resistance are so small that they can be ignored.

18. An elevator, as illustrated, is being lifted up in an elevator shaft by a steel cable. When the elevator is moving up the shaft at a constant velocity:



(a) the upward force on the elevator by the cable is greater than the downward force of gravity.

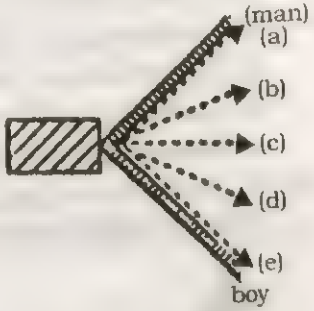
(b) the amount of upward force on the elevator by the cables equal to that of the downward force of gravity.

(c) the upward force on the elevator by the cable is less than the downward force of gravity.

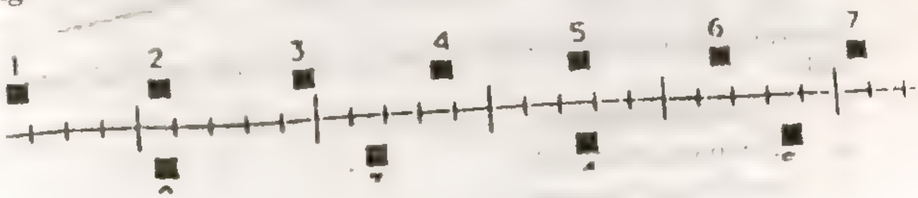
(d) it goes up because the cable is being shortened, not because of the force being exerted on the elevator by the cable.

(e) the upward force on the elevator by the cable is greater than the downward force due to the combined effects of the air pressure and force of gravity.

19. Two people, a large man and a boy, are pulling as hard as they can on two ropes attached to a crate as illustrated in the diagram to the right. Which of the indicated paths (A to E) would most likely correspond to the path of the crate as they pull it along?

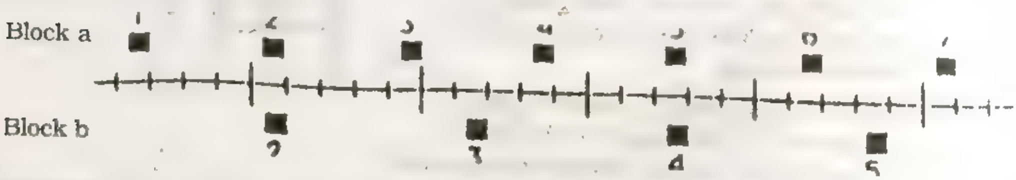


The positions of two blocks at successive 0.20 second time intervals are represented by the numbered squares in the diagram below. The blocks are moving toward the right.



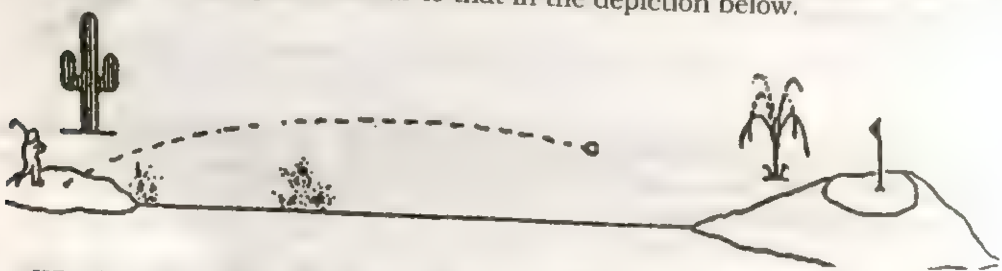
20. Do the blocks ever have the same speed?
    (a) No.
    (b) Yes, at instant 2.
    (c) Yes, at instant 5.
    (d) Yes, at instant 2 and 5.
    (e) Yes, at some time during interval 3 to 4.

The positions of two blocks at successive equal time intervals are represented by numbered squares in the diagram below. The blocks are moving toward the right.



21. The acceleration of the blocks are related as follows:
    (a) acceleration of "a" > acceleration of "b"
    (b) acceleration of "a" = acceleration "b" > 0.
    (c) acceleration of "b" > acceleration "a".
    (d) acceleration of "a" = acceleration of "b" = 0
    (e) not enough information to answer.

22. A golf ball driven down a fairway is observed to travel through the air with a trajectory (flight path) similar to that in the depiction below.

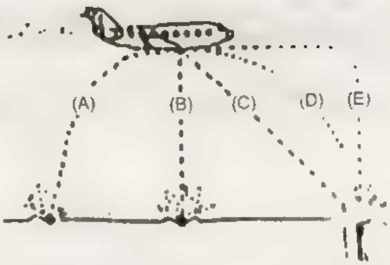


Which of the following force(s) is(are) acting on the golf ball during its entire flight?

1. the force of gravity
2. the force of the "hit"
3. the force of air resistance

(a) 1 only
(b) 1 and 2
(c) 1,2, and 3
(d) 1 and 3
(e) 2 and 3

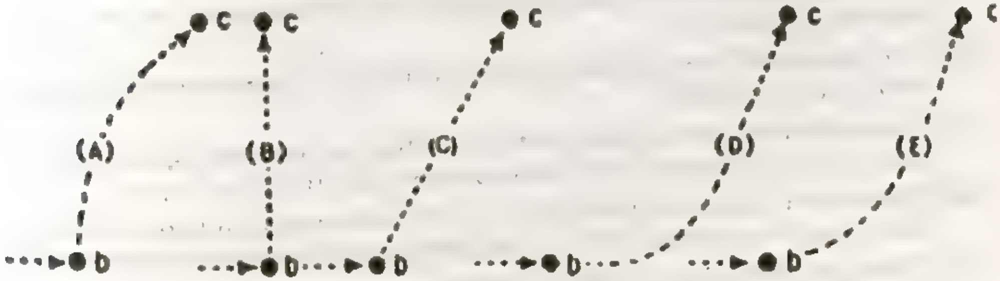
23. A bowling ball accidentally falls out of the cargo bay of an airliner as it flies along in a horizontal direction. As seen from the ground, which path would the bowling ball most closely follow after leaving the aeroplane?



When answering the next four questions, refer to the following statement and diagram.

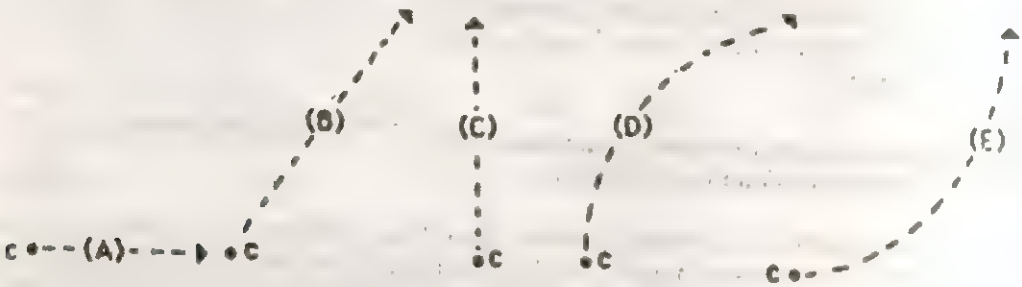
A rocket, drifting sideways in outer space from position "a" to position "b" is subject to no outside forces. At "b", the rocket's engine starts to produce a constant thrust at right angles to line "ab". The engine turns off again as the rocket reaches some point "c".

24. Which path below best represents the path of the rocket between "b" and "c"?



25. As the rocket moves from "b" to "c", its speed is
 (a) constant.
 (b) continuously increasing.
 (c) continuously decreasing.
 (d) increasing for a while and constant thereafter.
 (e) constant for a while and decreasing thereafter.

26. At "c" the rocket's engine is turned off. Which of the paths below will the rocket follow beyond "c"?



27. Beyond "c", the speed of the rocket is:
 (a) constant.
 (b) continuously increasing.
 (c) continuously decreasing.
 (d) increasing for a while and constant thereafter.
 (e) constant for a while and decreasing thereafter.

28. A large box is being pushed across the floor at a constant speed of 4.0 m/s. What can you conclude about the forces acting on the box?
 (a) If the force applied to the box is doubled, the constant speed of the box will increase to 8.0 m/s.
 (b) The amount of force applied to move the box at a constant speed must be more than its weight.
 (c) The amount of force applied to move the box at a constant speed must be equal to the amount of the frictional forces that resist its motion.
 (d) The amount of force applied to move the box at a constant speed must be more than the amount of the frictional forces that resist its motion.
 (e) There is a force being applied to the box to make it move but the external forces such as friction are not "real" forces, they just resist motion.

29. If the force being applied to the box in the preceding problem is suddenly discontinued, the box will:
    (a) stop immediately.
    (b) continue at a constant speed for a very short period of time and then slow down to a stop
    (c) immediately start slowing to a stop.
    (d) continue at a constant velocity.
    (e) increase its speed for a very short period of time, then start slowing down to a stop.

Effectiveness of Discovery Learning Method with Respect to Achievement in Biology

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INSTRUCTION in Science offers tremendous possibilities for making use of diverse, alternative learning resources and learning strategies in the classroom. Teaching strategies play significant role in enhancing the learning abilities of students. In the words of Gabel and Bunce (1994) Many of the Goals of Science Education will be realised once teachers orient their teaching towards understanding of concepts.

It has to be lamented however that science instruction in the secondary classroom continues to be dominated by teacher talk, minimum classroom participation of the students and teacher control as is evidenced by a number of research studies. Conventional lecture method continues to be quite popular among secondary school teachers (Pushpam, 1997; Nair, 1979; Nayar and Puspam , 2000).

Discovery learning approach is not an innovative method. But despite its tall claims of realisation of instructional objectives and enhancement in learning it is not very popular among secondary school teachers in the classroom. Discovery learning has been found to be ideal for learning certain select topics in Biology. It provides scope for direct learning experiences, whole classroom participation and interactive classroom environment. Studies have reported that such classroom environments are ideal for cultivating learning skills, scientific temper and arousing curiosity and instilling motivation.

According to Dewey (1963) Discovery Learning provides opportunities for student participation and Learning by experiment. Teaching through mere verbal Instruction was discouraged. When students learn by discovery they are active and provides diverse learning opportunities for different levels of students. In Discovery Learning goal is perceived, the pace is self-determined and learning becomes both self-sequenced and goal directed.

As Lewin and Potter (1947) reported that children get answers to questions by finding out their own routes to discovery. Students must be given opportunities for free exploration and should be given chances to participate actively in the learning process. According to Anderson and Koutnit (1972) Environmental approach provides chances to apply textbook knowledge in an interpretation of local phenomenon. Even though suitable outdoor resources are available to learn science through discovery method, students are generally forced to memorise facts and principles without understanding meaning of terms, concepts and practical implications (Driver, 1993; Selberg, 1972; Wellington, 1983).

Objectives of the Study

The study had the following objectives:

(1) to study the effectiveness of Discovery Learning Method with respect to achievement in Immediate post test achievement Delayed Memory achievement and Extent of Forgetting

(2) to compare the immediate post test achievement scores of sub samples based on sex, locale and management of school.

Methodology

The study was conducted on 216 Standard VIII students of various schools in Thiruvananthapuram District. A pre-test achievement test based on the select topic was conducted. The treatment groups were assigned to Experimental Group and Control Group based on the Pre-test achievement scores. For statistical analysis of data the scores were equated based on Pre-test achievement scores (Only those receiving scores between M- and M+ comprised the treatment groups). Accordingly the treatment groups comprised of 120 students (Experimental Group, N=60; Control group, N=60). The topic Feeding adaptations in birds was taught using Discovery Learning Method. All the steps of Discovery learning were resorted to. After experimental teaching which extended to two weeks a post-test achievement test was conducted. To ascertain tbe retention of the content learnt a retention test was administered two months after experimental teaching.

Experimental procedure

Discovery learning exploits the inquisitive nature of students. Discovery learning enables students to pursue the path by themselves through the practice of Discovery. The concept of Adaptations was taught by selecting the subject theme Feeding adaptations in birds as an example. Studies have reported that Discovery learning is most suited for topics in which students have considerable background and to hierarchically arranged subject matter (Selim and Shrigley, 1983; Shulman and Tamir, 1976; Wittrock; 1966) This particular example gives ample scope of direct learning experiences, familiarity of the topic, ability to structure the topic hierarchically and availability of learning resources. Students observed different types of birds, categorised the different birds based on the structure of the beak. Through a sequence of classroom activities involving inferences, prediction and problem solving, students associated a particular beak type to a particular feeding habit. Ultimately, students generalise on the structure of beak of birds feeding on grains, fruits and nuts, fishes, flesh of prey, nectar and insects. Through these learning sequences students discover the concept of Adaptations, equip themselves to apply this concept in their immediate surroundings and attempt to understand the structural. peculiarities seen in living organisms.

The control group was taught employing a textbook oriented method. The topic Adaptations was introduced

giving emphasis on the structural peculiarities of living organisms seen in the surroundings. The topic was explained in detail using examples cited in the textbook (desert adaptations of camel and cactus). Evaluation of student learning was attempted by obtaining immediate feedback.

After experimental teaching which extended to two weeks a post-test achievement test was conducted. Comparisons of the Experimental (Discovery Learning Group (DLG)) and control group (lecture Method Group (LMG)) was done based on the achievement scores obtained.

Results and Discussion

Analysis of results indicated that there was significant difference between Experimental and control groups with respect to Immediate post-test achievement and Delayed memory test. It can be concluded that teaching through Discovery learning enhances the immediate post-test achievement. This gain in achievement score is also reflected in the Delayed Memory test (retention test). This implies that discovery learning facilitates effective learning as content learnt can be recalled more easily and effectively. This result is supported by the Extent of Forgetting scores (difference between Immediate post achievement and Delayed memory achievement scores) which reveal a significantly higher mean score for the control group. This implies that the Extent of Forgetting was higher for the control group.

Details in Table 2 revealed that there was no significant difference between boys and girls with respect to the Immediate post test and Delayed memory achievement scores. However, the retention power of girls was found to be better than boys when taught using Discovery learning. Students of Rural and Urban schools did not exhibit any significant difference with respect to Immediate post-test achievement, Delayed memory achievement and Extent of Forgetting. It can be concluded that the achievement in Biology was not influenced by the locale of the school when taught through Discovery Learning Method. Students of private schools were found to have better retention than students of government schools when taught using Discovery Learning Method.

Implications of the Study

The core of the teaching process is the arrangement of environments within which the students can interact and study how to learn (Dewey, 1916). Teachers should take into account the academic, social and cultural correlates of the students before selecting a particular method for teaching. The task variables of the topic too should be taken into consideration. All this necessitates a flexible and dynamic approach to teaching. According to Joyce and Weil (1992) students are not identical and therefore, what helps one person learn a given thing more efficiently may not help another as much. However, an educational treatment that helps a given

type of student a great deal does not damage another type of students. Considerable attention has to be paid to the 'learning history' of students, their cognitive and personality development, social skills and attitudes. Attempts to improve the quality and effectiveness of teaching and learning in schools must look into the understanding of what people in classrooms do at present. Teachers must be willing to adopt new practices and try out new approaches in a quest for improvement (Stoutworth, 1994).

Table 1: Comparison of achievement scores of Discovery Learning Group (DLG) and Lecture Method Group (LMG). (Total Sample)

Sl. No.	Tests	Treatment groups (N=60)	Mean	Standard Deviation	Critical Ratio
1.	Immediate post test achievement	LMG DLG	35.92 29.3	5.92 5.4	6.4*
2.	Delayed memory achievement	LMG DLG	26.58 20.85	7.1 4.3	5.3**
3.	Extent of Forgetting	LMG DLG	10.1 11.2	2.5 2.2	2.5*

Table 2: Comparison of achievement scores of sub samples

Sl. No.	Tests	Variables	Sub Samples	Mean	Standard Deviation	Critical Ratio
1.	Immediate post test achievement	Sex	Boys Girls	36.29 35.59	6.25 5.61	0.45 (NS)
		Locale	Rural Urban	36.83 35.31	4.88 6.45	0.99 (NS)
		Management of School	Private Government	37.30 34.22	5.39 6.10	2.08 **
2.	Delayed memory achievement	Sex	Boys Girls	24.89 27.91	6.89 7.17	1.65 (NS)
		Locale	Rural Urban	27.75 25.67	7.59 6.81	1.11 (NS)
		Management of School	Private Government	24.12 29.41	7.72 5.15	3.17

3. Extent of Forgetting	Sex	Boys Girls	12.82 7.81	7.82 7.56	2.52*
	Locale	Rural Urban	9.25 10.75	8.21 7.95	0.71 (NS)
	Management of School	Government Private	13.42 6.15	8.45 5.27	4.07**

** Significant at .01 level
* Significant at .05 level
NS - Not Significant

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Teaching Science and Technology in Schools

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Need to have science and technology education coherently from the early childhood to adulthood is a message reiterated by several educationists. These two domains have contributed enormously in improving the quality of human life. Science, until now, was offered as a part of general education upto ten years of schooling. From upper primary school to secondary, it was being taught as a single discipline and only some inputs of technology were included in the science curricula. However, now, National Curriculum Framework for School Education (NCERT – 2000) has recommended that science and technology should be taught as a subject of the general education. The document advocates strongly that technology should be integrated with science teaching and its main aim should be scientific and technological literacy. The inclusion of science and technology as a subject in general education is based on same premise. There had been a widespread belief that it was necessary to link the studies of technology and science. The complete separation between these two areas in the school curricula is often artificial. The difficulties encountered in combining these two domains can be attributed in part to the fact that the technology education is a relatively newcomer to the scene and its relation to science education has yet to be clearly defined (Kimbell, 1994).

The present article is an attempt to establish interrelationship between science and technology and, thus, justifying the integration of science and technology as a subject at upper primary and secondary level.

Etimological links of Science and Technology

If we go through the definitions of science and technology we would find some links between the two domains.

Science: It is both a body of knowledge and the process of acquiring it (Frederic, 1960). It concerns with the fundamental knowledge of the universe, the world and its environment. The scientific process combines aim of doing to the aim of understanding what is done.

Technology: The Oxford English Dictionary defines technology as the scientific study of the practical or industrial arts and also as application of science. This definition shows the dual character of technology. We can look technology as an application of science but also as a science in its own right; one that explains the practical arts. Technology as application of science makes it organically linked to science. Thus, when science is applied to solving of practical problems it is described as technology. Another definition states: Technology is concerned with solving

problems, meeting needs. In technology, the tasks, making the artefact or other form of solution, is the end, the resources are means. The knowledge and skills of science may be some of the resources, but other skills such as those of design, of craft or of evaluation of solutions, may also be needed (Black, 1984). In this definition also knowledge and skills of science have been considered very important for the development of technology.

Nature of Science and Technology

Science is universal and its principles and laws could be verified anywhere. It does not vary with geography of a place or with economic, social or political conditions whereas technology can acquire ethical moral overtones and invite to itself levels like moral or immoral, human or cruel even socialistic or capitalistic.

Because of the universal nature of science and its application to technology suitable to all cultures a close link with technology and society is established.

Science and Technology for Society

Joint application and use of scientific knowledge and understanding and technological artefacts have led to satisfying the needs of the society whether it is for economic, indudstrial, basic living requirements or for leisure. That is why the common curriculum of both the domains is prepared as a component of general education covering the areas such as food, health and nutrition, agriculture, energy and industry. This clearly suggests that these two subjects should not be separated at school level.

Processes of Science and Technology

When different experiments are developed and performed, improvisation is made, appropriate technological device is used, the instruments and equipment are handled based on scientific principles and laws, industrial processes, and products are studied and various static and working models are developed, different processes of science and technology are developed amongst the students together (Whittle, 1993). The science processes developed are; experimentation, taking observations, collection of data, classification, analysis, making hypothesis, drawing inferences and arriving at conclusion and the technological processes are; identify a real problem, define a problem, consider possible solutions, carry out some initial tests, select a possible solution, design a practical device, make the device, test the device in real situation, make improvements and test the modified device.

Interdependence between Science and Technology

Discoveries in science have paved the way for the evolution of new technologies. At the same time, technology has been instrumental in the development of science. There are many historical and current examples of the co-evolution of scientific knowledge and technological development which prove above statement. For example, development in

space technology has led to accumulation of knowledge regarding space and side by side that knowledge led to further development of technology. Another very important example is the invention of microscope which brought into motion different activities for establishing different optical principles, astronomical and biological understanding and further developments of the telescope and microscope (Mason, 1974). Gairis in the theoretical knowledge about telescope contributed to the further development of the telescope by designing new types and by formulating the law of reverse relationship between light intensity and square distance.

The modern science is mainly dependent on technology which has been highlighted by many workers (Galison, 1997; Pickering 1995. Traweek, 1988). Thus, it can be said safely that technological knowledge and scientific knowledge are increasingly intertwined and mutually constitutive. In nutshell, it can be stated that the science supports technology by providing knowledge and methodology but on the other hand technology also supports science by providing equipment. This shows interdependence of science and technology.

Educational Objectives and Science and Technology

Education at every stage has dual functions: it is a preparation for further studies and a preparation for future life and work. Traditionally education systems have drawn a distinction between the two, associating science education with the former and technology education with the latter. However, if we look more deeply into the areas of science education and technology education, we find that each is a facet of other and their separation has had undesirable effects on the quality of education as a whole and extent of opportunities available for the development of every child. Therefore, if we keep the objectives of education in mind, it is more appropriate that science and technology should be interwined in the curriculum for study in general education.

Pedagogical Perspective of Integration of Science and Technology

Science asks the question of why the phenomena occur while technology deals with how the understanding of phenomena can lead to serve human purpose. Thus, when we bring science and technology together, we bring knowledge and action together which pedagogical sounds better as knowledge and action are interdependent which can be learned successfully if brought together in learning situation. Technology in science curriculum can infuse many components of the curriculum and aims to empower students to practical capability in real life situations. It complements academic dogma which states that learning is facilitated by "Knowing that" with "knowing how" (Layton, 1988). Thus, for better understanding of both the subjects it can be recommended both the disciplines should be integrated together.

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Preparation of Acetanilide

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For sometime there has been some problem of preparing the acetyl derivative of amines as the common reagent acetic anhydride is banned since it was being used for preparing some banned chemicals.

Many books have recommended the use of pyridine as a base for this reaction. Pyridine has been found to have adverse effect on the human body.

We, therefore, recommend the following procedure to be followed to get the acetyl derivative of amino compound. Test case being aniline.

Reagent for acetylation: Acetyl chloride in Glacial acetic acid

Experiment Redistilled aniline (1ml, b.p. 183°C) is taken in a dry boiling tube. To this glacial acetic acid (1ml, b.p. 116°C) is added. It is mixed thoroughly and to this mixture acetyl chloride (1ml) is added in small lots (0.3ml at a time).

The mixture becomes warm, (if the boiling tube becomes unbearable to touch, it should be cooled under tap water).

After the addition of the whole of acetyl chloride, the mixture is heated for five minutes in a boiling water bath. It is cooled and ice-cold water (~ 10ml) is added into the tube with constant stirring. Acetanilide separates out as white powder. It is then filtered and washed with water till the filtrate is neutral to litmus, Washing is done in order to remove excess acid.

The solid is dried. The yield of the crude solid is found to be 0.9550 g.

The entire amount of solid is crystallised from hot water when white shining needles of ace, tanilide are obtained. Crystals are filtered and dried (yield 0.75g). It melts sharply at 114°C (lit m.p. 114°C).

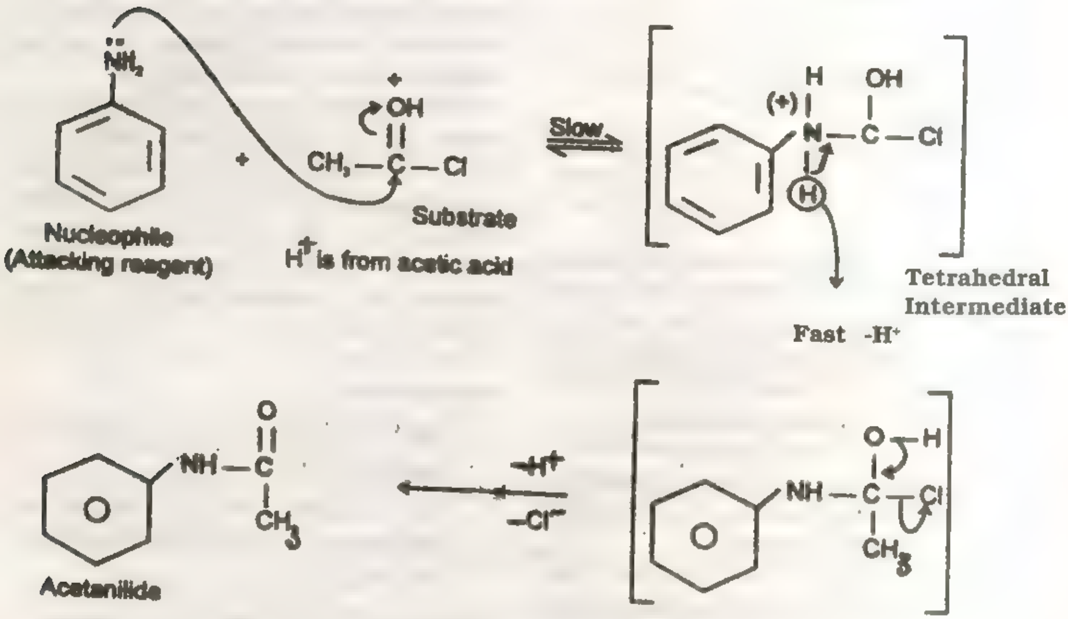
Precautions

1. The apparatus used should be perfectly dry.
2. The vapours coming out during the addition of acetylchoride should not be inhaled.

Advantages of the use of reagent — "Acetvl Chloride in acetic acid" for acetylation

1. It does not require the use of pyridine. Pyridine absorbs moisture and should be distilled every time before use.
2. The use of freshly distilled aniline gives the product in almost same amount as obtained by acetic-anhydride - procedure.
3. Acetanilide can be obtained even if aniline is not freshly distilled though the yield obtained would be less.
4. This method can be used anywhere in India as the chemicals needed are easily available everywhere.

Mechanism - Nucleophilic Substitution reaction proceeding through tetrahedral mechanism



Percentage of Calcium in Egg Shells (Farm/Desi) by Complexometric Titration

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PERCENTAGE of calcium by mass in Farm and Desi egg shells is described complexometrically. Titrimetrically EDTA is used as an Intermediate solution. After dissolving the egg shells in aqua-regia, solution of 1g/L is used for estimating the amount of calcium at pH 10. In Farm egg shell and Desi egg shell percentage of calcium by mass is found to be 36.94% and 37.64% respectively. Results obtained from ISO – certified Laboratory is 37.60% in both types of egg shells. Theoretically percentage of permissible error calculated from the formula used is $\pm$ 2.1%. Experimentally results obtained are in agreement with the ISO-certified Analytical Testing report.

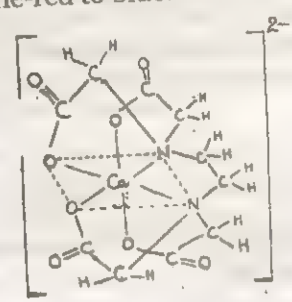
For the last three decades, major emphasis has been laid on qualitative tests of cations/anions/functional group etc. as a practical work in Chemistry at secondary/higher secondary level. National Science Curriculum Framework – 2000 developed by the NCERT has given importance on qualitative as well as quantitative work. In the light of this, an attempt is made in this experimental study to find out the percentage of calcium present in the egg shells (Farm as well as Desi) quantitatively at higher secondary level in Chemistry.

In Rajasthan state, Ajmer district is centre of poultry farms, these poultry farms are means of sustenance for small segment of the society. As a common practice, egg shells are generally thrown away as waste product. Literature study reveals that egg shells contain metals. However, an exact volumetric method for the estimation of calcium metal from egg shells at higher secondary level within stipulated time period is not available. An attempt is made to describe a new method which is given below.

Theory

Disodium salt of ethylenediamine tetra acetic acid ($Na_2C_{10}H_{14}O_8N_2$) is versatile reagent for the determination of amount of calcium quantitatively by complexometric titration using Eriochrome black – T as an indicator. Ethylene diamine tetracetic acid is a hexa dentate ligand. It forms a stable complex with calcium metal ion at pH 10 having the following structural formula

Here EDTA acts as a ligand. Metal and ligand reacts here in a ratio of 1:1. Colour change at the end point will be from wine-red to blue.



Solution Required

1. M/100 Magnesium acetate tetrahydrate of A.R. quality as a primary standard.
2. Buffer solution of pH = 10 (by taking requisite amount of liquor ammonia and ammonium chloride)
3. Approximately M/100 EDTA solution.
4. Eriochrome black – T or solo chrome as an indicator. (Dissolve 0.3g in a solution containing 15 mL of triethanolamine and 5 mL of ethanol). Colour of indicator solution is dark blue.
5. Sample solution of egg shells. (One gram egg shall is dissolved in aqua-regia. Excess of HNO_3 is boiled off and dilution is made with distilled water to make strength of egg shell solution = 1g/litre). Two solutions of sample are made, one with the Farm egg shell and the other with Desi egg shell, which are labeled as PE-I and DE - II respectively.

First of all EDTA is standardised with primary standard magnesium acetate. Disodium salt of EDTA is abbreviated as H_2Y^{2-}, metal as M^{2+} and eriochrome black – T indicator as HIn^{2-}. First metal ion reacts with indicator. Colour of the indicator will change from blue to wine-red.

$$\underset{\text{Colourless}}{M^{2+}} + \underset{\text{Blue}}{HIn^{2-}} \rightarrow \underset{\text{Wine-red}}{MIn^{-}} + H^{+} \quad \text{...(A)}$$

This wine-red solution is titrated with EDTA at pH=10

$$\underset{\text{EDTA}}{H_2Y^{2-}} + \underset{\text{Wine-red}}{MIn^{-}} \rightarrow MY^{2}\,\underset{\text{Blue}}{HIn^{2-}} + H^{+} \quad \text{...(B)}$$

Procedure

1. Magnesium acetate solution 10 mL is taken in a titration flask with the help of a pipette.
2. Added 4-5 mL buffer solution approximately into the above titration flask.
3. 4-5 drops of Eriochrome black – T were added as an indicator. Colour of the solution in the flask changed due to formation of MIn^{-} as shown in reaction (A).
4. Then it was titrated with EDTA solution taken in a burette till two concordant readings were obtained and exact molarity of EDTA was determined.

Similarly procedure was followed for egg shell solution, and molarity of egg shell solution was determined. Finally percentage of calcium was calculated.

Observations and Calculations

Mass of magnesium acetate taken
= 0.214 g

Molecular mass of $(CH_3\,COO)_2\,Mg.4H_2O$
= 214.0g

0.214 g magnesium acetate is dissolved in 100 mL distilled H_2O. Therefore, molarity of Magnesium acetate solution

$$= \frac{0.214 \times 1000}{100 \times 214} M = \frac{M}{100}$$

Set I : Titration of Magnesium Acetate vs EDTA

Volume of Magnesium acetate used for each titration = 10mL

S.No.	Initial Reading	Final Reading	Volume of EDTA used
1	0.0	10.2	10.2 mL
2	10.2	20.3	10.1 mL
3	21.0	31.1	10.1 mL

Therefore, volume of EDTA used = 10.1 mL

Molalrity of EDTA solution =

$$\frac{M \times 10}{100 \times 10.1} = \frac{M}{101}$$

Set II: Titration of sample PEIvs EDTA

Strength of sample taken = 0.997 g/L
Volume of sample PE-I used for each titration = 10 mL

S.No.	Initial Reading	Final Reading	Volume of EDTA used
1.	0.0	9.8	9.8mL
2.	10.0	19.3	9.3 mL
3.	20.3	29.3	9.3 mL

Therefore volume of EDTA used = 9.3mL

Molarity of sample PE-1 = $\frac{M \times 9.3}{101 \times 10}$

Strength of sample PE-I in terms of calcium metal

$$= \frac{9.3 \times 40}{101 \times 10 \times .997} \text{ g/L}$$

$$= 0.3694 \text{ g/L}$$

Percentage of calcium by mass

$$= 0.3694 \times 100 = 36.94\%$$

Percentage of calcium by mass in sample PE-I obtained from ISO-certified Analytical Testing Report = 37.60%
Therefore, percentage error = 1.76%

Set III : Titration of sample DE-II vs EDTA

Strength of sample DE-II taken = 1.010 g/L
Volume of sample DE-II used for each titration = 10 mL

S.No.	Initial Reading	Final Reading	Volume of EDTA used
1.	0.0	9.8	9.8 mL
2.	10.0	19.6	9.6 mL
3.	20.0	29.6	9.6mL

Therefore, volume of EDTA used = 9.6 mL

Molarity of sample $DE-II = \frac{M \times 9.6}{101 \times 10}$

Strength of sample DE-II in terms of calcium =

$$\frac{9.6 \times 40}{101 \times 1.01 \times 10} \text{ } g/L = 0.3764 \text{ } g/L$$

Percentage of calcium by mass = 37.64%

Percentage of calcium by mass in sample DE-II obtained from ISO-certified Analytical Testing Report = 37.60%

Therefore percentage error = 0.10%

Result and Disussion

In Farm eggs percentage of calcium by mass in egg shells is found to be 36.94% and in Desi egg shells, it is 37.64%. ISO-certified report of Shri Ram Institute for Industrial Research, Delhi reveals that the percentage of calcium by mass in

Farm egg shells as well as Desi egg shells is 37.60%. Percentage of error found in Farm and Desi egg shell is 1.76% and 0.10% respectively. Within experimental errors percentage of permissible error calculated from the formula used is found to be ± 2.1 %.

Percentage of calcium by mass in Farm and Desi egg shells is 36.94% and 37.64% respectively. So egg shells can be used as source of calcium.

Qualitatively Mg^{2+} and Ca^{2+} were tested in the chemistry laboratory. Tests of Ca^{2+} ions were positive whereas tests of Mg^{2+} ions were negative. Analytical study reveals that the percentage of magnesium is 0.43%, which is quite less therefore, percentage of magnesium has been neglected while calculating the percentage of Ca^{2+}

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Masculine Image of Physics: Breaking the Mould for Attracting Girls to Physics Courses

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MANY PHYSICS educators (Kelly, 1976 and Macooby, 1970) say that women's position in physics is a depiction of their position in society as a whole. Kelly further adds that over and above this, there are special problems in physics instruction which centre on society's expectations and attitudes towards girls in science. Because physics in the classroom reflects those outside pressures, therefore, physics teachers and physics must be concerned with setting their own house in order.

According to Kelly, "More women should be involved in physics. This is not a demand for quotas, but for steps to encourage girls, interest in, and enjoyment of physics, so that they become involved in the subject. If physics is seen as an integral part of a general education, taught for intellectual satisfaction and excitement it provides, then it should be made available in a way which appeals to both boys and girls. If the aim is to produce further research physicists, then source of potential talent must come from both girls and boys."

Brief Literature Overview

As far as the cognitive learning is concerned, it is a well-established fact now that there is no difference between boys and girls. If lesser number of girls are attracted to physics courses, it is the matter of attitude and methods of teaching physics seem to have a queer image created by media as being remote, difficult and masculine. Also, popular media projection of scientists as eccentrics seems to be keeping girls away from physics courses. Dodge (1966) gives the example of Russia, where deliberate attempt was made through films and books with scientists as heroes and do-gooders to improve the image of scientists and attract more girls to science courses and research in science subjects.

Gender and Physics: What Do Educators Say and Reveal?

Some important observations and findings in respect of the relation between science (physics in particular) are as follows:

- Girls may loose interest in physics because such interest is not expected of them by teachers and society in general. If physics is seen as a subject for boys, girls become unwilling to take up physics as a subject of study (Kelly, 1976).
- Textbooks unconsciously reflect the general low opinion of women's place in society. Manyatimes physics

textbooks give an impression that physics is not done by but for women (Kelly, 1976).

- If more of social implications of science as well as science as a means for societal good is projected along with its content then girls are able to correlate to it better. (Ormerod, 1975).
- Girls are generally more reinforceable than boys, more encouraged by success and more discouraged by failure and retreat from the subject. (Shayer, 1972)
- Emphasis on discovery methods, experimental work when done collaboratively can enhance girls participation in learning physics. However, any difference between boys' and girls' learning styles are group differences, and individuals do not fall fit the group pattern. Therefore, there is a need to use a range of teaching styles in verbal or experimental, expository or discovery, best suited to individual's learning style (Babikian, 1971).
- Studies (Des, 1975 and Ormerod, 1975) have shown that girls in single-sex schools are more favourably disposed towards physics than girls in co-educational schools. Probably the reason is that in the only girls institution, there is no strong tendency to link physics as difficult and a boys' subject. This emphasises the point that sex-typing of subjects is stronger in co-educational schools.

Reflective Analysis

On the basis of the qualitative data in the form of foregoing views of physics educators and some facts from studies, the following factors contribute to the exclusion of girls from physics courses.

- Prevalence of an attitude to project physics as a difficult and masculine subject.
- Media image about scientists as crazy people.
- Use of instructional methods like lecturers and individualistic learning which project physics as remote, abstract and difficult subject.
- Learning environment and evaluation system which are hurtful to the self-esteem of girls.
- Gender-bias in textbooks and emphasis on competitive learning rather than cooperative learning.
- Lack of inclusion of sociology of science and value system in curriculum organisation and transaction.

The severity of these factors in Indian situation need to be studied at the school and higher education levels of physics instruction.

In Conclusion

There is a need to review physics curricula to make them female friendly in the light of the factors mentioned in the paper. Also, educational research with gender forms needs to be done by the institutions of higher education to make a case for changing the methods of physics teaching.

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BOOK REVIEW

Quantum Mystery

RAJAT CHANDA
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THE CLASSICAL physics based on Newtonian mechanics is highly successful in explaining the macroscopic world, i.e. the world of planets, stars, galaxies and even for understanding the larges cale properties and structures of the universe as a whole. However, the classical laws of physics fail miserably in the microscopic world of molecules, atoms and subatomic particles. In this miniature world, laws of quantum mechanics are applicable. It was Max Planck who in 1900 was first to introduce the quantum hypothesis namely that the emission and absorption of energy can happen only in discrete lumps called quanta. This hypothesis was needed to resolve a problem in the classical theory of electromagnetic radiation.

Although the Planck's quantum theory resolved the radiation problem it did not attract much attention. It was mainly because the idea was out of line with the then current thinking, and also since no independent evidence for the quantum could be found. In 1905, Einstein used the Planck's quantum hypothesis to view light as parcels of pure radiation energy. He also assumed that light is created and absorbed by the matter in discrete parcels of energy. Thus, the concept of light-quantum or 'photon' was born. This picture of bullets of light interacting with matter was very different from the established theory of absorption and emission of light waves by matter. Using the idea of photons, Einstein was able to successfully explain the phenomenon of photo-electric effect in which light causes electrons to be ejected from metals.

The jewel in the quantum theory's crown was, however, Bohr's planetary model of the atom with its discrete orbits for the electrons circling the nucleus. This was direct application of the quantum ideas of Planck and Einstein to atomic dynamics. Although Bohr's theory was successful in explaining the spectra of hydrogen and hydrogen-like atoms, yet there were many unanswered questions. For instance, some of the spectral lines were shown to possess fine structures. At first, some refinements to the Bohr's theory seemed to account for such results. However, the relative intensity or brightness of spectral lines remained inexplicable. Clearly, Bohr's theory was not the whole story. Some physicists started suspecting that the problems would not be resolved by tinkering with the Bohr's model with its well-defined electronic orbits. The ad hoc Bohr quantum condition could only be justified in terms of de Broglie waves associated with electrons; only those discrete electron orbits are allowed for which the orbit length (or circumference) equals an integral multiple of the de Broglie wavelength associated with electrons. All other orbits disappear due

to destructive interference. However, for large objects such as balls and bullets, the associated de Broglie wavelengths are so small that quantum effects are completely negligible, and the laws of classical mechanics are valid. These laws are, however, known to be deterministic in that the position and momentum of a particle can be simultaneously measured with unlimited accuracy. As a result, if the underlying law of motion is known, the fate of the particle is known for all times to come. However, the deterministic laws of classical world are not valid in the miniature world of quantum mechanics which is governed by the principle of indeterminacy or uncertainty principle due to Heisenberg.

Although the conceptual foundation of quantum theory seems enigmatic, it works brilliantly and forms the basis of understanding the fundamental properties of all matter. Also, it has been successful in explaining many of the observed phenomena including superconductivity, superfluidity and Bose-Einstein condensation. Despite the phenomenal success of quantum theory, strangely, no final consensus has been reached on some aspects of the theory. Therefore, attempts towards re-examination of its foundation and understanding the meaning of its concepts, as well as questions regarding its completeness, continue even to this day.

The book under review unfolds the mystery of the quantum world in a down-to-earth and interest-arousing manner. It discusses the laws of quantum mechanics and a host of amazing quantum phenomena. The probabilistic interpretation of quantum mechanics based on the principle of indeterminacy, met with considerable resistance in the early days of its development. Schrodinger wrote a criticism of the standard view of quantum mechanics, and illustrated it with an example involving a cat. This led to the famous cat paradox. A beautiful account of this paradox, and a description of how to resolve it, appears in the book. Some recent progress made in understanding the connection between the quantum and classical worlds is also highlighted. The book finally summarises the current status of our understanding of the quantum theory.

Written in a simple language and lucid style the book will be useful to students and teachers at all levels. However, some of the sentences appearing in the book are lengthy indeed; they need to be curtailed for better clarity of the subject.

Certainly, the book deserves respectable place in the shelves of all school and college libraries.

P.K. Mukherjee
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CONSTITUTION OF INDIA

Preamble

WE, THE PEOPLE OF INDIA, having solemnly resolved to constitute India into a **SOVEREIGN SOCIALIST SECULAR DEMOCRATIC REPUBLIC** and to secure to all its citizens:

JUSTICE, social, economic and political;

LIBERTY of thought, expression, belief, faith and worship;

EQUALITY of status and of opportunity; and to promote among them all

FRATERNITY assuring the dignity of the individual and the unity and integrity of the Nation;

IN OUR CONSTITUENT ASSEMBLY this twenty-sixth day of November, 1949, do **HEREBY ADOPT, ENACT AND GIVE TO OURSELVES THIS CONSTITUTION.**

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